ISO TC184/SC4/WG10 N219

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PRODUCT DATA REPRESENTATION AND EXCHANGE

Part: n/a **Title:** **Industrial Framework Model**

Purpose of this document as it relates to the target document is:

Primary content	Current status:
Issue discussion	Version 0.95
Alternate proposal	
Partial content	

ABSTRACT:

This paper discusses the issue of providing an underlying structure to Application Modules and it proposes an Industrial Framework Model (IFM) against which Application Modules should be evaluated. It is recognised that in addition to the IFM there may be other models against which Application Modules could be evaluated. Part of the IFM also addresses Application Protocols and provides a model against which they can be evaluated. It is assumed that readers are aware of the concept of Application Protocols defined from a set of Application Modules.

KEYWORDS

Document status/dates (dd/mm/yy)

Part Documents		**Other SC4 Documents**	
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Comments to Reader:

Comments and questions on this document are welcomed. Please direct them to the editor.

AMENDMENT HISTORY

Issue Number	Nature of Changes	Date Incorporated
	Industrial Information Model, presented at WG10 Workshop	Dec 1997
0.92	Draft - Reviewed within PDES, Inc.	13 July 1998
0.95	Addition of sections 3.7, 3.8, 5.2, 6.6, 6.7, 6.8, 12, 13, and Appendix E Plus minor updates and restructuring of document.	14 Dec 1998

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1. Introduction

Currently STEP Application Protocols are built using information models from a pool of resources. It is felt that while most of the information models produced for STEP are of good quality there has been insufficient work on ensuring that they fit together properly and operate together to support the whole product life-cycle. A review of known STEP development shows that the scope of STEP goes beyond the usual definition of Product Model Data, it also includes for example information about the means for

- designing the product,
- making,
- operating,
- supporting
- and disposing of the product.

Much of Logistics work is involved with information about the support factory and its capabilities, e.g. available facilities, equipment, maintenance staff and skills.

In addition to the above, STEP contains some basic concepts about Product Models, for instance it includes ways of representing and presenting information about the product.

A new architecture for STEP is emerging based on a modular use of resources. It is critical that these resources are verified to ensure the overall success of this effort. The purpose of this document is to describe a top down view of the concepts in STEP to complement and check the bottom up work on the current set of Application Protocols and Application Modules.

This paper proposes an Industrial Framework Model (IFM) against which both Application Protocols (APs) and Application Modules (AMs) should be evaluated. While the general structure of the IFM is believed to be correct, it is known that when APs and AMs are evaluated against the IFM, issues will arise with the APs, AMs and the IFM. Adjustments to any of these three items may be needed to maintain an integrated and consistent STEP standard.

While the IFM is seen as important it is recognised that there may be other models that would also be useful.

The next section defines the IFM while the rest of the document discusses the rationale for the model and major relationships between the various categories. Later sections describe how some subjects relate to the IFM and some guidelines on deciding the structure and scope of modules.

A fundamental tenet of this paper is the belief that there are fundamental similarities between different industries. STEP must incorporate these similarities but allow for the differences.

1.1 Relationship of the IFM to the Application Modules

One of the uses of a Framework is to categorise both AMs and APs and use this categorisation to aid the user finding the correct AM or AP. The diagram below shows three separate concepts and shows how they relate to each other. These concepts are: -

Library - this is the complete set of standards documentation that define Application Modules and Application Protocols.

Catalogue - is a set of summary descriptions of AMs and APs and a mechanism (web based) that allows the user to search for the Module that meets their requirements.

Framework - is a framework like the one contained within this document that lets us categorise Modules. When it is incorporated into the Catalogue, it allows the Catalogue to provide more user-friendly methods of searching for the modules that are of interest.

This document provides one Framework but does not preclude that there will be other equally valid alternatives.

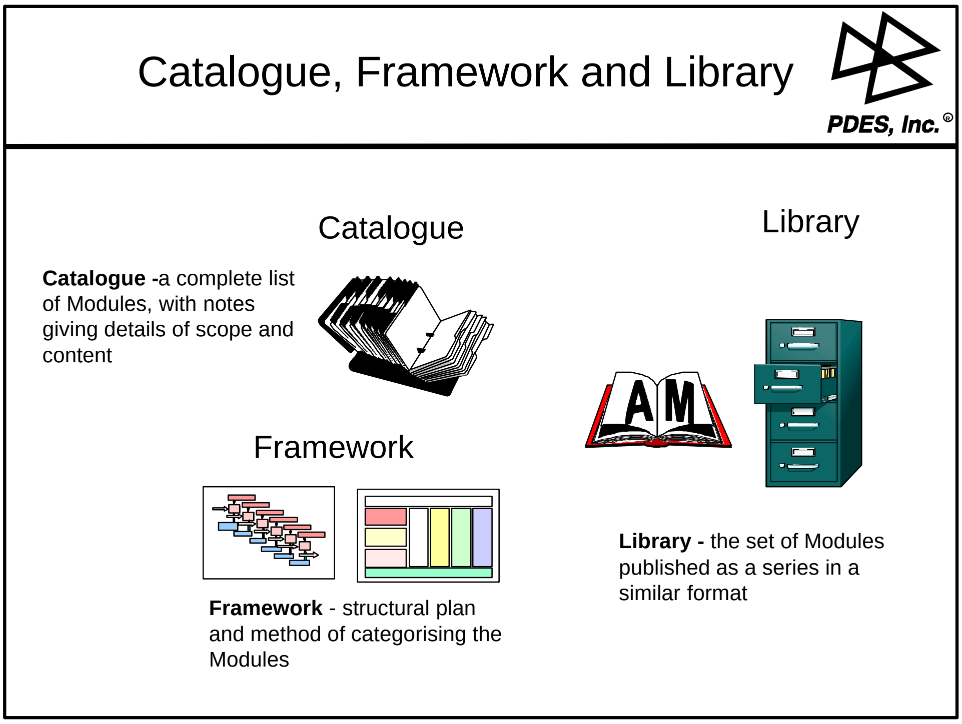


Figure 1- Catalogue, Framework, Library

2. Definition of IFM

STEP Application Modules (AMs) will contain information models about particular concepts. These AMs will be used together in Application Protocols (APs) to satisfy the industry need to exchange information about products.

The Industrial Framework Model consists of a three-layer model that covers the scope of Application Protocols and Application Modules. Two of the layers are extended by the inclusion of an Idealised Product Life Cycle (IPLC) and an Industrial Information Model (IIM). The IFM, and the IPLC and IIM, provide a way of categorising APs and AMs.

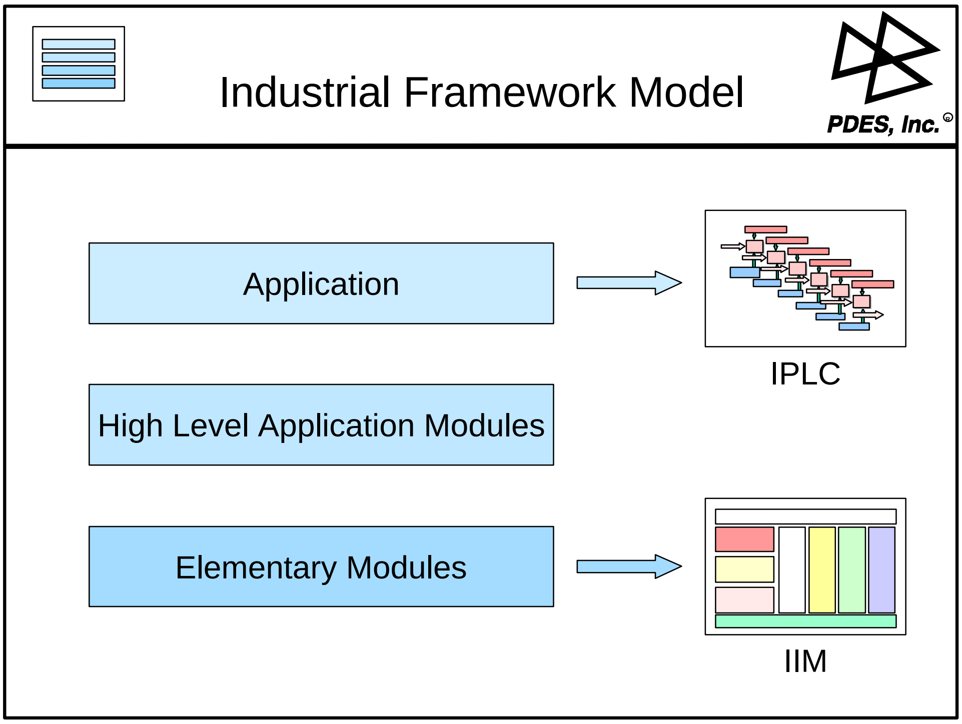


Figure 2 - Industrial Framework Model

The layers of the IFM are: -

1. Application, Application Protocols fit into this layer. The IPLC provides a way of categorising and evaluating APs.
2. High Level Application Modules, Application Modules that define concepts wider than the IIM categories and define how concepts will be used from an Industry point of view.
3. Elementary Modules, these are Application Modules that contain independent concepts that are fairly general and have little application context. The IIM provides a way of categorising these AMs.

2.1 Idealised Product Life Cycle

The IPLC is a process model that describes a basic Product life cycle. The model is at a level that should hold true for most manufactured products. It should be possible to map other process models or terminology to the IPLC. Application Protocols support information flows and hence the IPLC flows can be used to categorise APs.

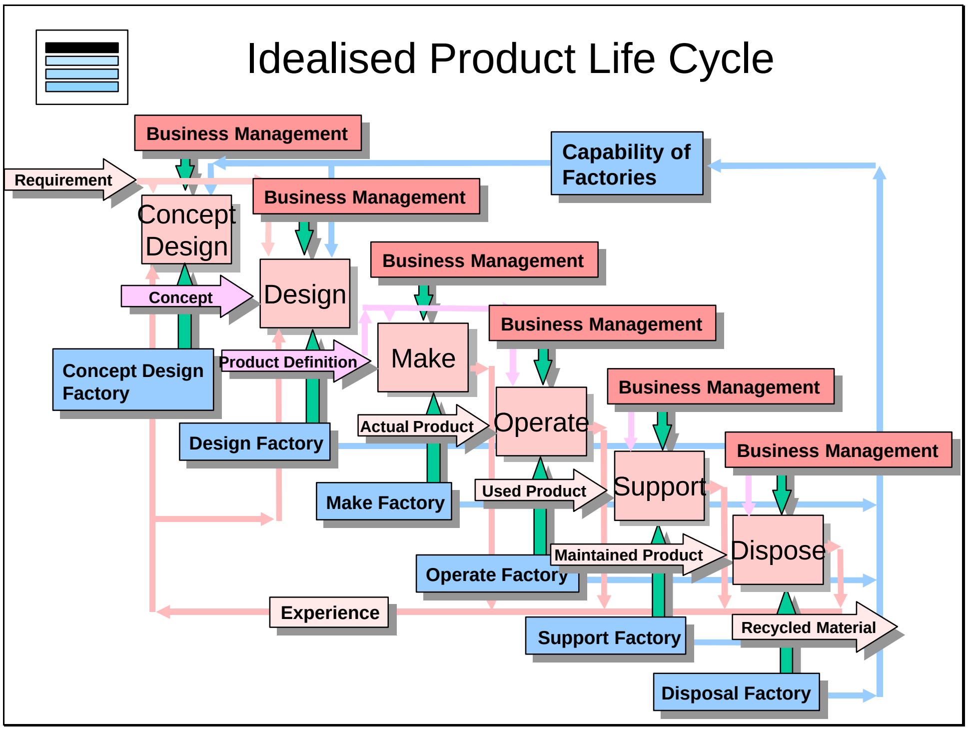


Figure 3 - Idealised Product Life Cycle

2.2 *Industrial Information Model*

The basic STEP Application Modules (AMs) will contain information models about low level concepts. The IIM is a way of categorising the concepts that are contained in these AMs. The following picture illustrates the set of categories proposed by the IIM.

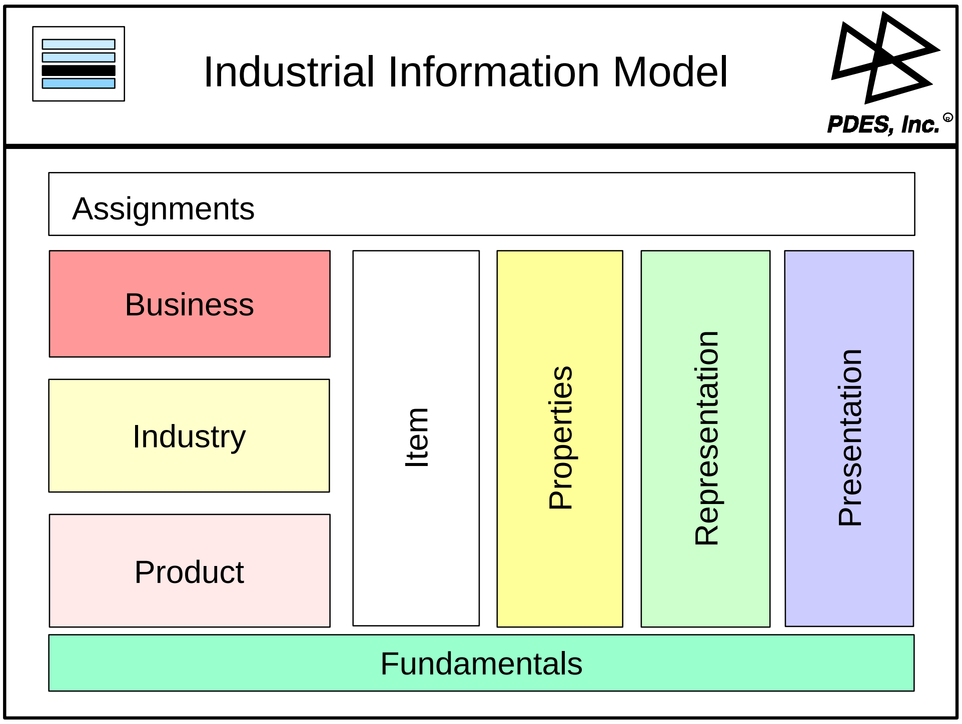


Figure 4 - Industrial Information Model

To fully understand these categories one needs to understand the process modelling used to identify the groups. The following sections of the paper describe the process and rationale for these categories.

A brief description of the categories follows: -

- **Product** data is information types that are valid for ALL products.
- **Industry** is information types specific to particular industry sectors or product types.
- **Business** is the information types that control or constrain for the Product Life-cycle processes.
- **Item** provides the link between the specific concepts within Product and Industry and the Properties of these items.
- **Properties** cover the concepts that characterise a thing or a product. E.g. Shape, structure, particular behaviour (e.g. thermal behaviour), material type
- **Representation** covers the various ways of representing product data.
- **Presentation** covers the ways of displaying or presenting information to people.
- **Assignments** contain the concepts that allow the others to be linked together to satisfy an industrial need.
- **Fundamentals** are concepts that apply across most of the other groups and even perhaps to non-Product data.

The following picture illustrates some information types or concepts mapped onto the IIM categories.

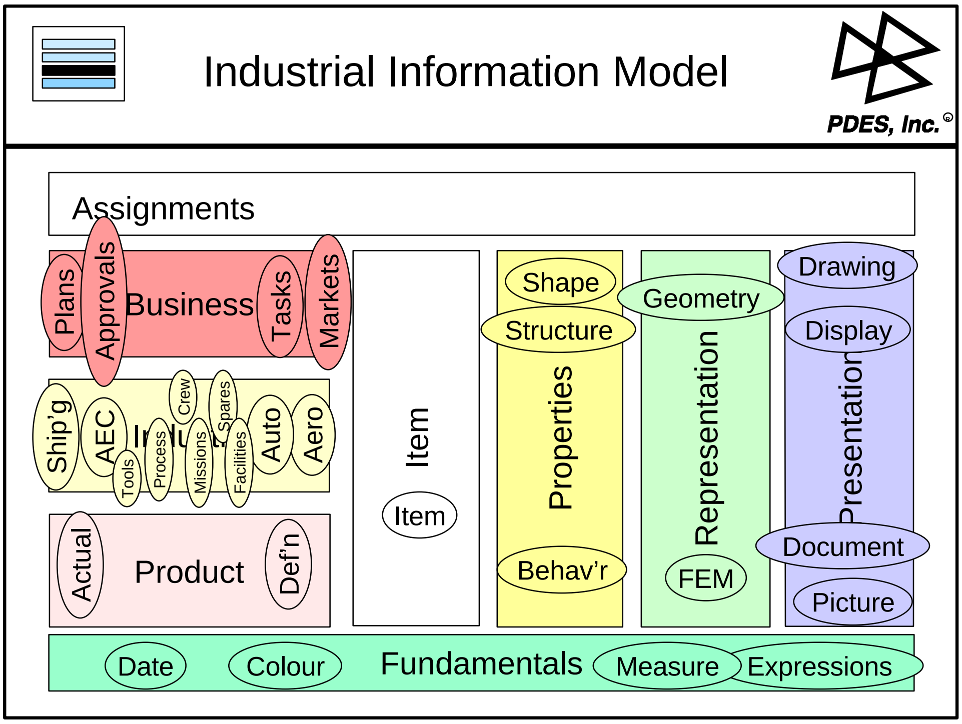


Figure 5 - Mapping Concepts to IIM

2.3 High Level Application Modules

The IIM is a way of categorising industry concepts at a certain (low) level of granularity. To satisfy an industry need to exchange data these low-level concepts will be combined into modules, and eventually into Application Protocols. These High Level Application Modules will span the categories in the IIM.

3. The Idealised Product Life Cycle

This section describes a basic Business process that STEP is there to support. Some of the types or categories of information that need to be supported can be seen from this model.

The goal of STEP is to support the Product life cycle. To model the processes involved in this life cycle the IDEF0 approach of modelling has been used.

Appendix E contains formal IDEF0 diagrams that define the Product life cycle process. The body of this report defines and describes the life cycle process using IDEF0 concepts but in a less formal presentation.

3.1 IDEF0

IDEF0 defines a process with its inputs, outputs, means and controls (or constraints).

A *process* is defined as an activity that adds value to its *input* and creates an *output*.

To perform the activity the *process* requires a set of *means* that allow it to function and the *process* is controlled (and constrained) in how and when it does the activity by the *controls*.

3.2 Idealised Product Life-Cycle Processes

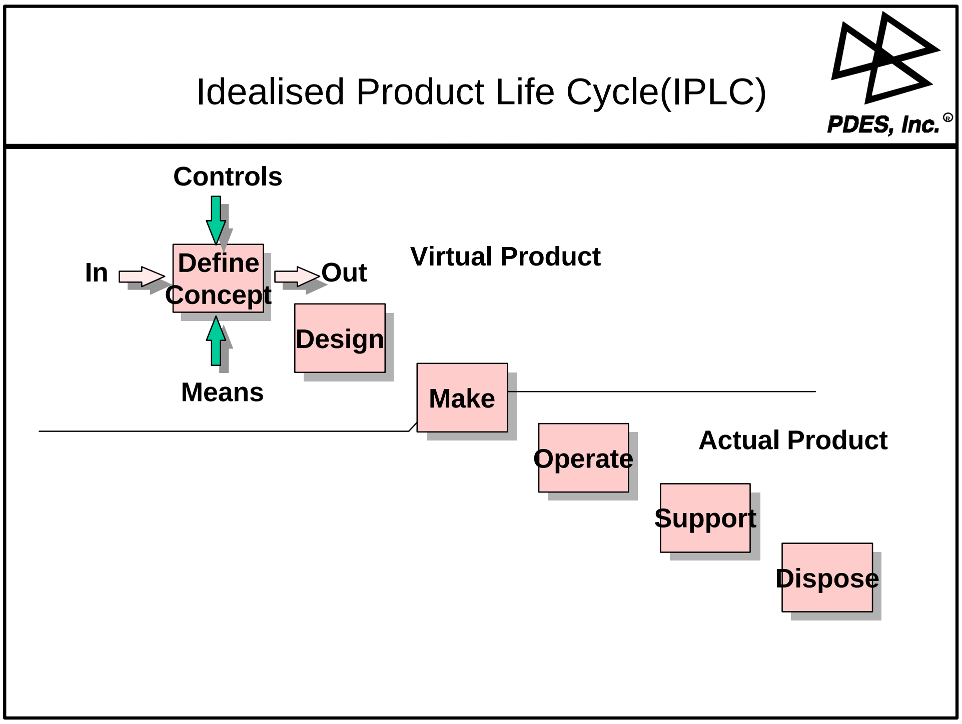


Figure 6 - IPLC - Processes

This diagram illustrates the typical processes for creating a product. To complete this picture the main inputs, outputs, means and controls must be identified for each process.

3.3 Inputs and Outputs

The main *input* into these processes is the **Requirements (**from the customer).

During the life cycle two main objects are generated: -

1. The design definition of the product - the **virtual product**
2. **Actual products** that are supposed to conform to the product definition

Mapping these inputs and outputs onto the process gives the following picture. Each of these items is a flow between the processes.

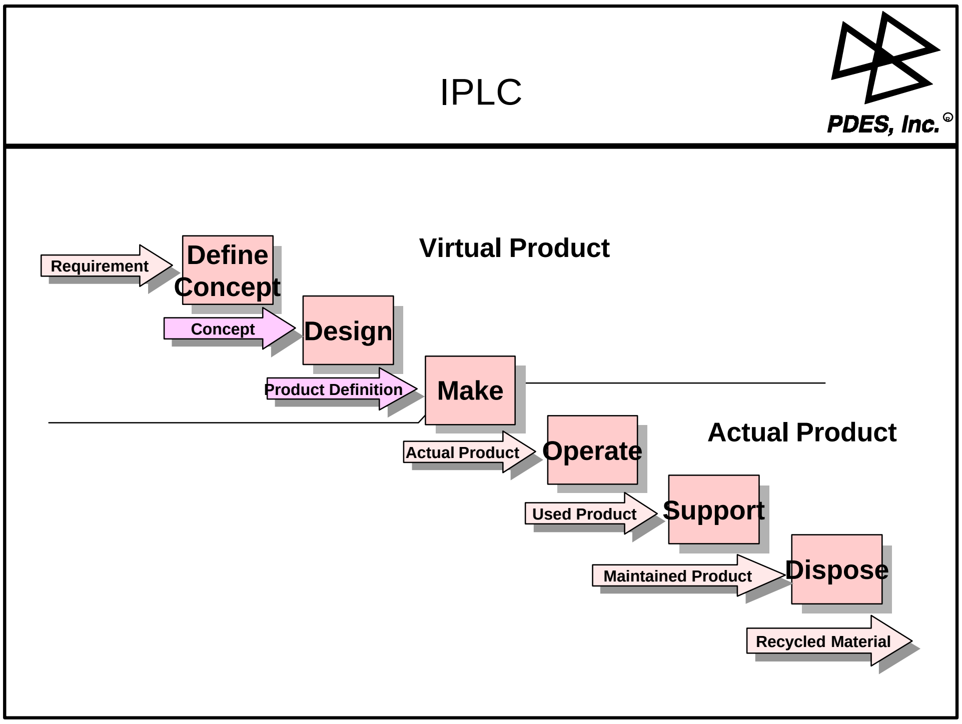


Figure 7 - IPLC - Inputs and Outputs

3.4 Means

The next addition to the process descriptions is to add the 'means' required to achieve each process in the life cycle.

The means for carrying out the Make or manufacturing process is the set of facilities, people, tools etc. that collectively carry out that process. In this paper this group will be called the Make Factory.

To carry out its function the Make Factory will have been created and previously will have been designed and built. While it is manufacturing products it will need to be maintained or supported. At the end of its useful life it will be disposed of. It therefore follows the same lifecycle as any other Product.

The next diagram illustrates how the lifecycle of the Make Factory (or the ‘Means’) relate to the life cycle of the Product.

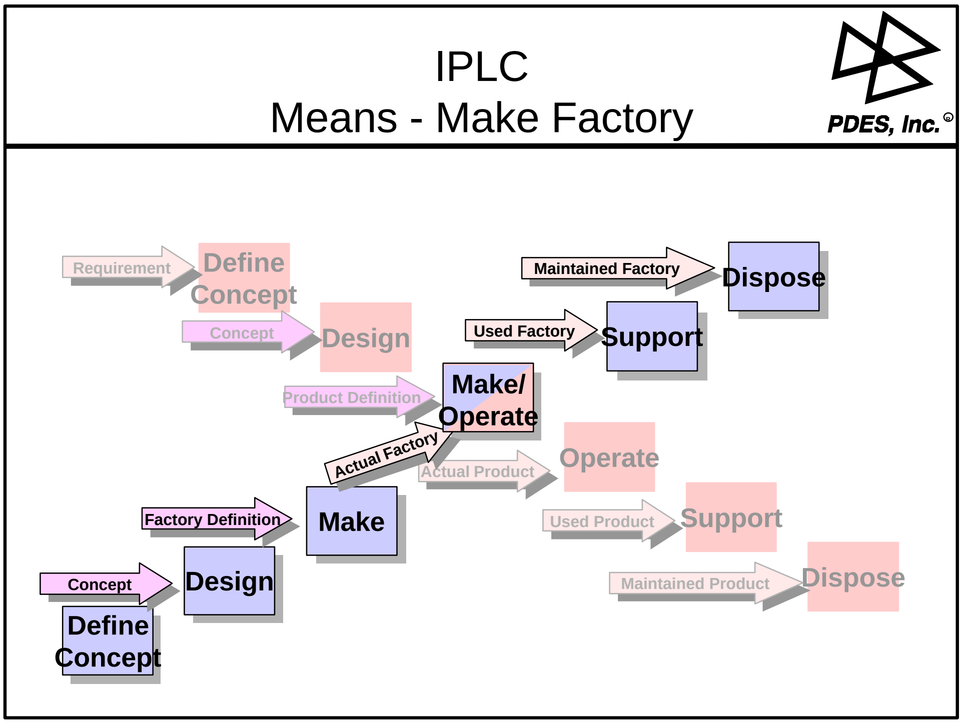


Figure 8 - IPLC - Means (Make Factory)

It can be seen that the lifecycle processes of the Make Factory are the same as for the Product,

- Define Concept of the Make Factory,
- Design the Make Factory,
- Make the Make Factory,
- Operate the Make Factory
- Support the Make Factory,
- Dispose of the Make Factory.

The only difference is that the Product is now the Make Factory.

Note that the 'Operate Make Factory' process is the same one as 'Make Product'.

The processes for creating the Design Factory, the Support Factory etc. follow the same structure.

This makes the life cycle of the Product

Define Concept	which is	**Operate Design Concept Factory**
Design	which is	**Operate Design Factory**
Make	which is	**Operate Make Factory**
Operate	which is	**Operate "Operate" Factory**
Support	which is	**Operate Support Factory**
Dispose	which is	**Operate Dispose Factory**

3.5 *Control of the Product Life Cycle*

To complete the basic process descriptions the *control* of the process must be added. Business management processes control the life cycle of the Product.

Building the ideas described so far into one illustration gives us a diagram that describes the typical process for creating a product.

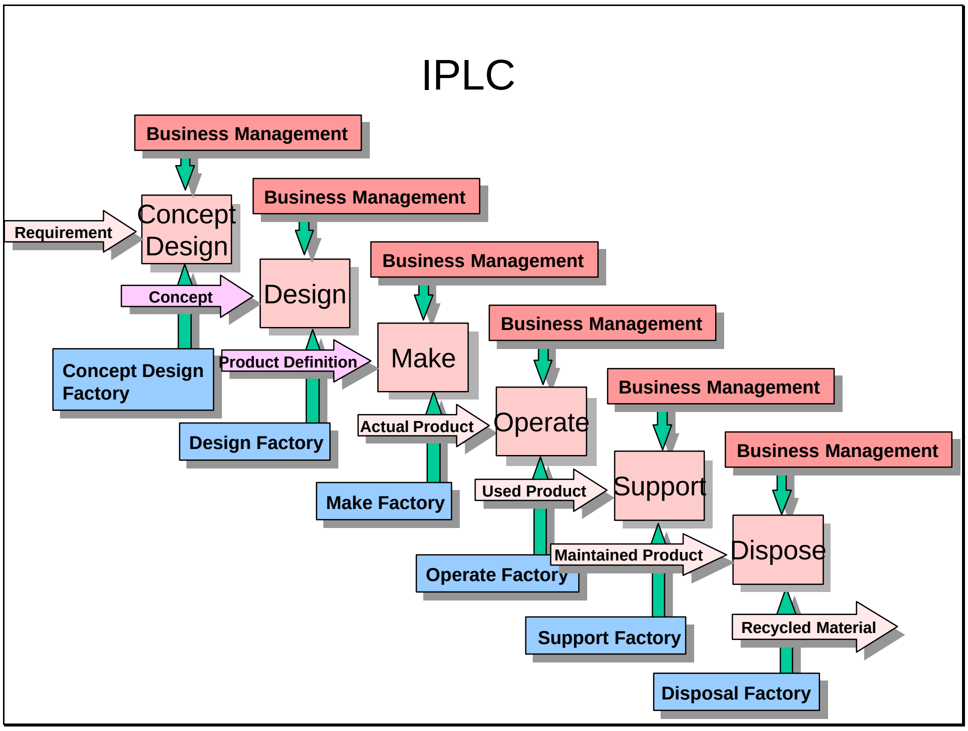


Figure 9 - IPLC - Controls

The diagram shows

- the requirement
- the virtual product (product definition)
- the actual product
- the means for creating the actual and virtual product. e.g. the Design Factory, Make Factory
- the Business Management data controlling the process, this includes items such as the resource, schedule, approval, regulations

Note that the Business Management data is NOT Product Data and hence STEP should probably not define information models for this area. However to support industry's data exchange requirements there **MUST** be interoperability between STEP and any standards that define this business information.

3.6 *Feedback*

The above diagram only shows the basic concepts and does not include any of the information flows that feedback information from the downstream processes (make, operate, etc) back into the design processes.

Adding these feedback flows give the complete life cycle.

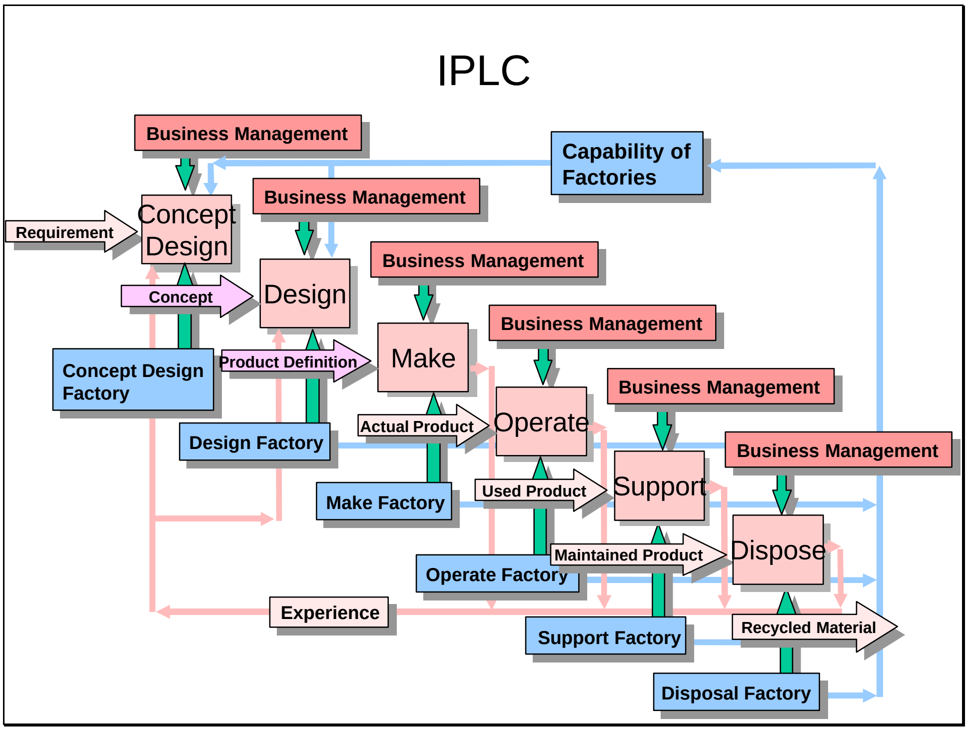


Figure 10 - IPLC - Feedback

Even in the concept stage the design work will take into consideration the past experience in making, operating, supporting or disposing of similar products. This **Experience** is feedback from the later processes into both the Concept and Design processes.

A Product must be designed in such a way that allows it to be manufactured, operated and supported. The Concept & Design processes are therefore constrained by the **Capabilities** of the Operator and the Make and Support Factories. For some industries this would also include the Disposal factory.

For some industries new factories may be required to make or support a new Product and the Make and Support Factories may be designed and created in parallel to the Product. In these cases the design of the Product would be constrained not by the actual capabilities of those factories but by the capabilities defined in the design of the factory. This design could be at either the: -

- Concept stage - ‘Factory Concept’
- Full design stage - ‘Factory Definition’ (as Designed)

3.7 Principles used in Defining the Process Model

This nearly completes the first level of the IPLC. A number of principles have been used in creating the IPLC and it is worth itemising these and checking that they have been applied correctly. The principles are: -

- The only information shown as an input to a process is that which is changed and has value added by the process. Information that is just used by a process, but not changed is shown as a means or as a control.

- The outputs from processes are the single fundamental item created by the process, this will normally be a composite information flow.
- Processes are only decomposed where the resultant model is generally true for all industrial products.
- The model tries to be neutral in that it does not to take any specific view (e.g. from a design, make or support perspective)
- All the processes must adhere to the same overall scope or context. In this case the processes that are truly part of the product life cycle. Some models combine the factory information and processes with that of the end product. This paper defines them following the same basic process. Hence activities such as train designers or support staff are not part of Product life cycle but of the Factory life cycle and should be supported by the same process and data model as the product. Similarly the generation of Material Properties data is part of Design Factory life cycle.

3.8 Idealised Product Life Cycle

If we now check the last diagram against the principles defined above we find some errors.

The **Requirement** is not an *input* to Concept since the process does not change it. It should be a *control*.

The **Product Definition** is not an *input* to the Make process since again the process does not change it. It should be a *control*. In fact it is a *control* on the Make, Operate, Support and Dispose processes.

These changes give the following Idealised Product Life Cycle.

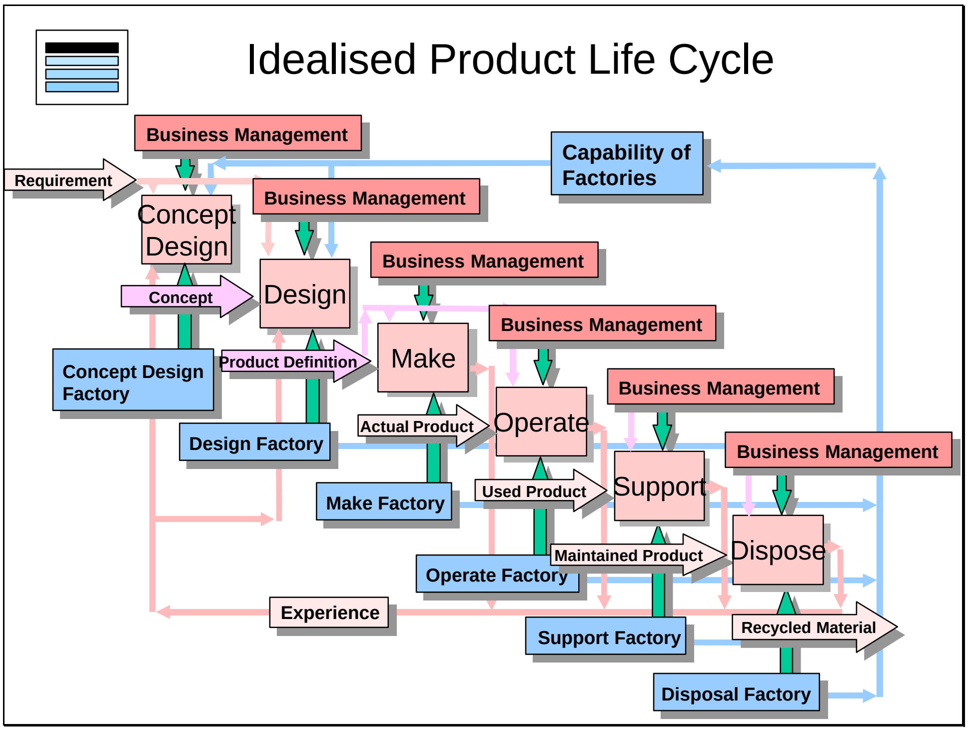


Figure 11 - IPLC - Idealised Product Life Cycle

A more formal version of this diagram is contained in Appendix E.

4. Lower Levels of Process within the Life Cycle

This section takes some of the processes in the IPLC and adds some detail to them.

4.1 Design Supply Chain

A term that is often used in conjunction with data exchange between companies is the supply chain.

There are at least two supply chains, the **design supply chain** and the **make supply chain**.

The following picture illustrates the design supply chain The picture shows the product decomposed into sub-systems and then into components. The **number of levels** of decomposition depends on the **complexity of the product.** . When a company designs its products it will often sub-contract the design of sub-systems or components to other companies.

In these cases the company will define the requirements (Sub-system Specification) to their sub-contractor and will receive back a definition (Sub-system Definition) of the design. These processes are of course true regardless of whether they are sub-contracted or not.

Section 5.2 - Interaction with Sub Product Life Cycles, page 23 discusses how this view relates to the IPLC processes.

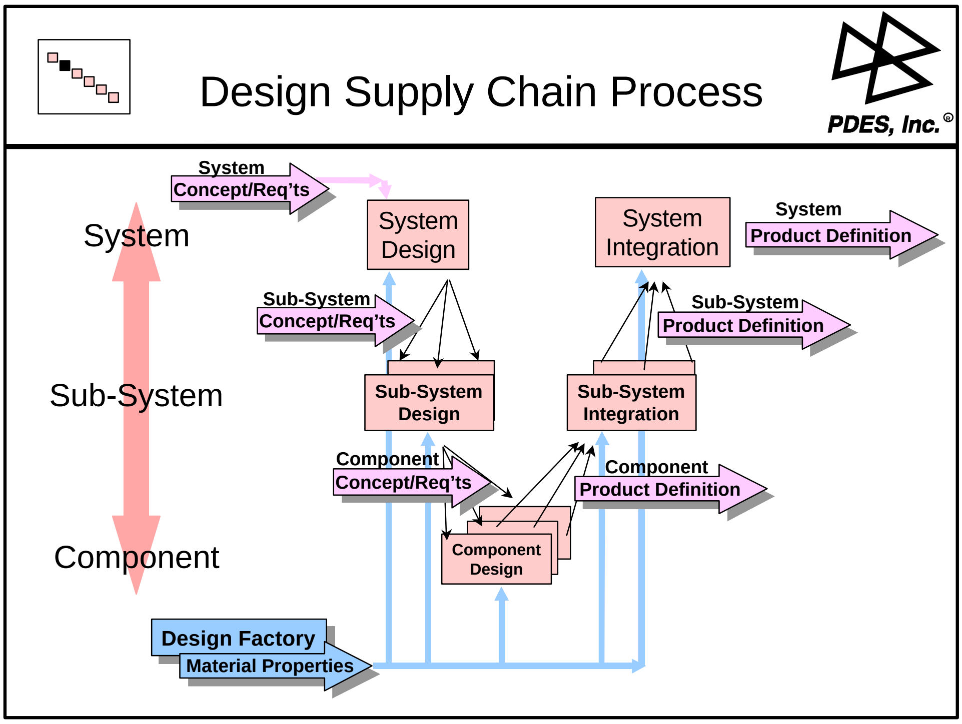


Figure 12 - Design Supply Chain Process

At all levels of the design process information about Material Types will be required. By the Component design stage the material the component will be manufactured from must have been decided and this process will require a definition of the behaviour of that material type.

4.2 Make Supply Chain

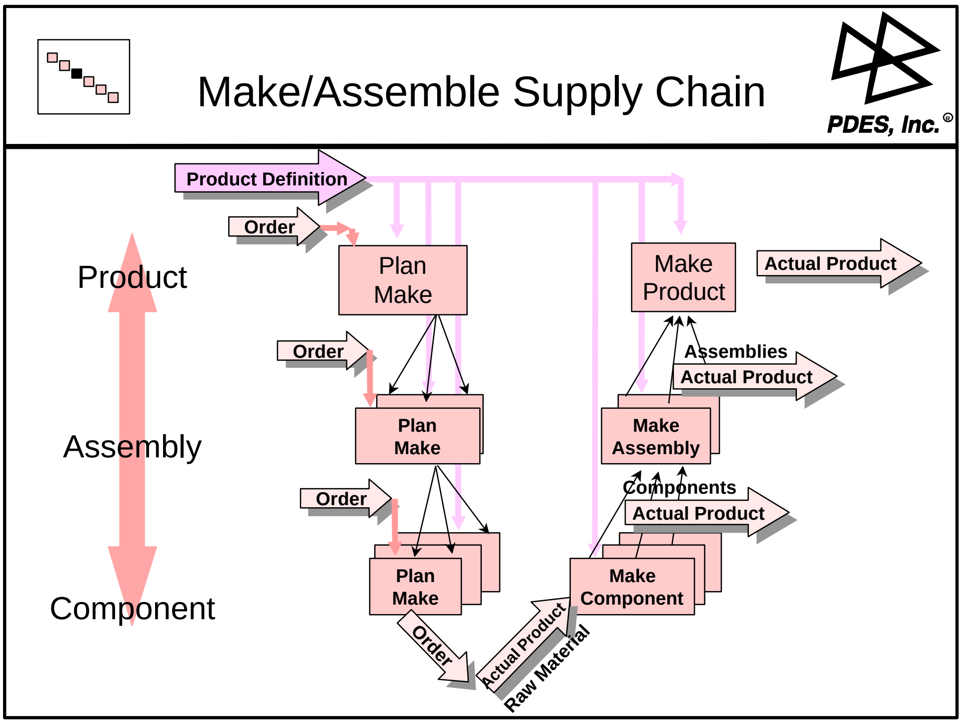


Figure 13 - Make Supply Chain Process

The Make supply chain is similar to the design chain. The process is initiated by an Order, which is cascaded down the supply chain. As parts are manufactured from Raw Material they are delivered up the supply chain where they are assembled and finally become the end product.

4.3 Design Analysis or Test process

At any level in the Design Supply Chain there is a need to ensure that the resultant Product will have the desired properties.

There are two ways of ascertaining the properties of the product.

1. By making a sample of the product and subjecting it to **actual physical tests**.
2. By making an **analytical model** of the product and using this to predict the product properties.

For most products some combination of these two approaches is used.

The diagram below illustrates the feedback from this testing back into the design process.

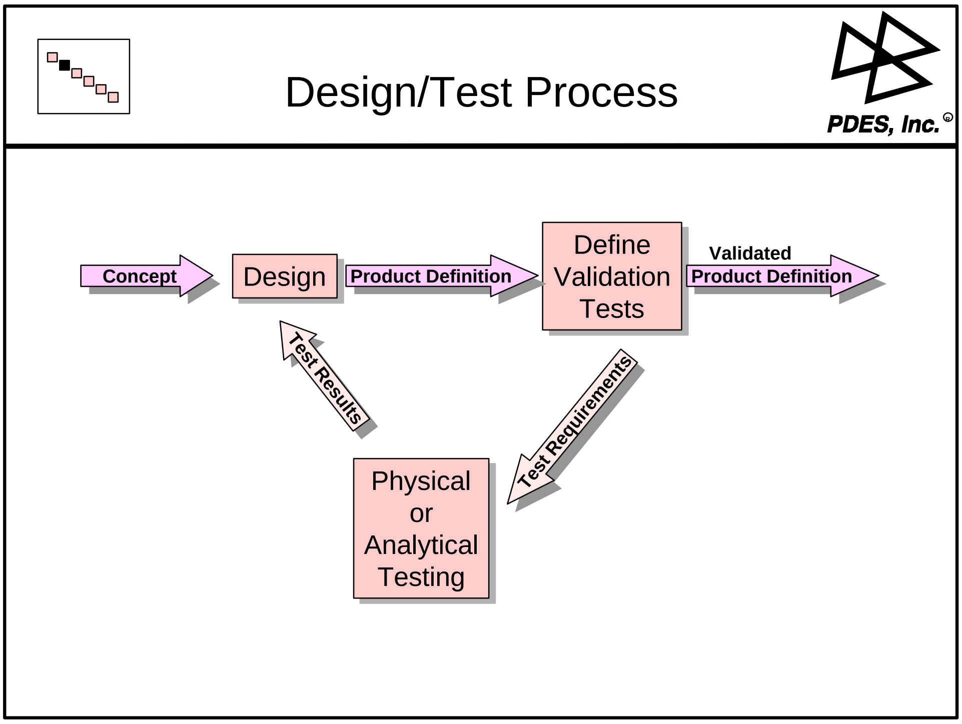


Figure 14 - Design/Test Process

4.4 Testing within Make, Operate, and Support

The testing of a product is also performed in the other processes within the IPLC. Similar diagrams to the one in the previous section also apply to these processes.

5. Interaction between Life Cycles

In earlier sections it was noted that various products follow the IPLC processes. This section details some of the interactions between the life cycles of such products.

5.1 Interaction with the Factory Life Cycle

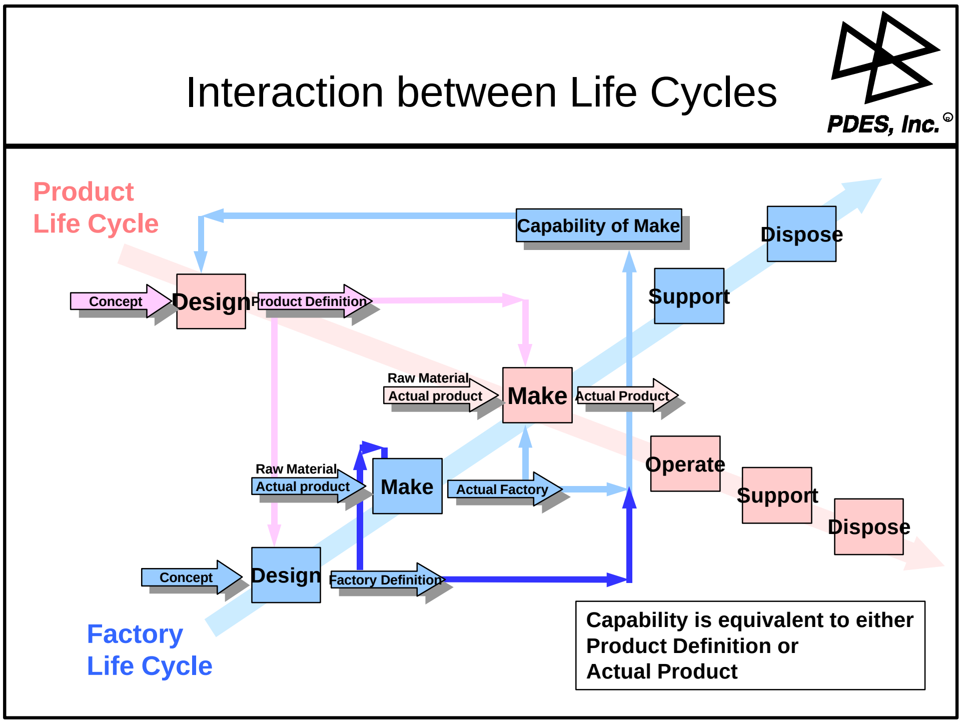


Figure 15 - Interaction between Life Cycles

The above diagram shows some of the interactions between the life cycle of the Product life cycle and the Make Factory life cycle. It is a more detailed version of the diagram described in 'Means' on page 14.

The diagram shows that:

- The actual Make Factory is the means for the Make process.
- The Product Definition is a constraint to the Make process but also can be a constraint to the Factory Design. **This enables the factory to be designed to make certain products.**
- The Capability of the Make Factory is a constraint on the Design process. This constraint can either be the capability of the actual factory or the intended factory (Factory Definition). **This enables the product to be designed so that the factory can make it.**

The last item is particularly important. From the diagram it can be seen that Capability is equivalent to either the Product Definition or Actual Product. This implies that a single information model should support both Capability and Product Definition or Actual Product. These are just different viewpoints on the same thing.

Similar diagrams and conclusions can also be draw for the other Factories, for instance the Support Factory. The capability of the Support Factory is an important information

flow within the Logistics world. The above implies that this flow should be supported by the same general information model as those used within the Product life cycle.

5.2 Interaction with Sub Product Life Cycles

In an earlier section, 'Design Supply Chain' on page 19, the supply chain was described. It can be seen from both the Design and Make supply chain pictures that the processes at each level of the diagram are the same. They are the same process but are different instances of the processes for different products (sub products/components).

In the Design picture the processes at the bottom, component, level are however shown differently. The reason for this is that the component has not been decomposed and hence the 'Integration' process is not required.

The following diagram shows

- Some of the IPLC processes replicated for each decomposition of a product (three levels shown as an example)
- How these process instances relate to each other.

Using the principles defined for creating the IPLC, only the top processes (product) are part of the IPLC, the lower processes (sub product) are additional instances of the same processes.

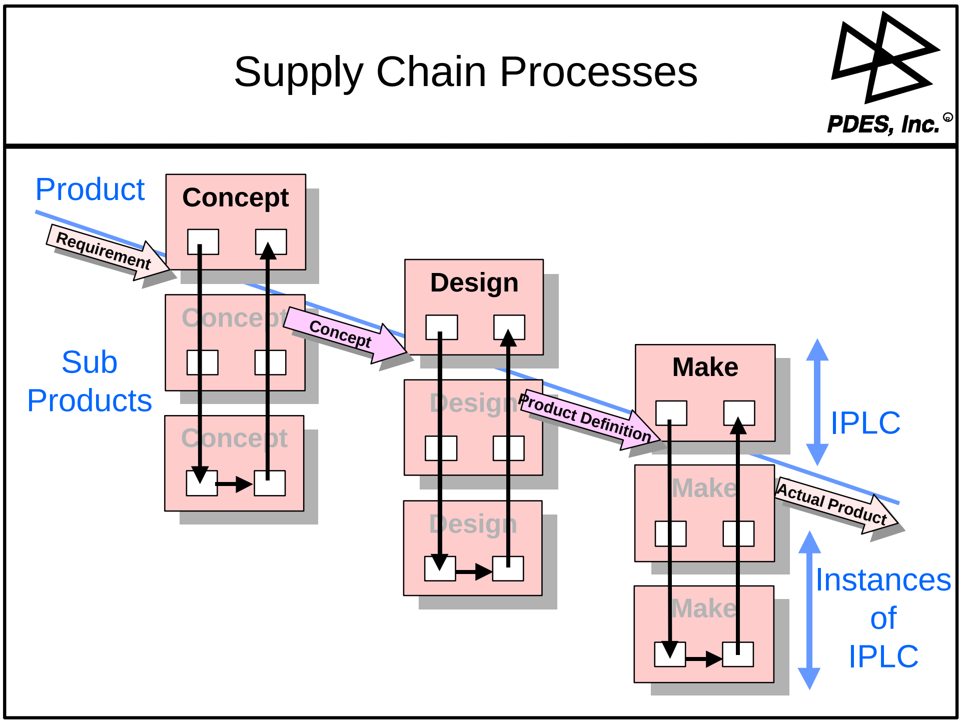


Figure 16- Supply Chain Processes

6. Major Relationships

This section describes some further concepts and major relationships that exist within industrial data. These have led to some of the categories in the IIM.

6.1 Presentation and Representation

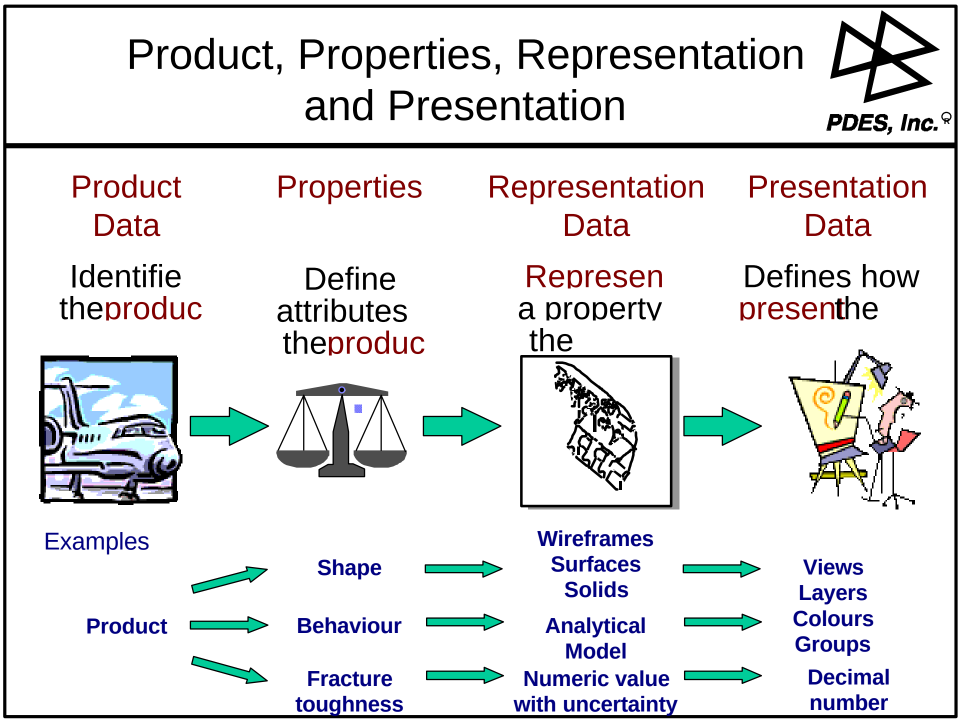


Figure 17 - Product, Properties, Representation and Presentation

This picture graphically describes the difference between:

- 'Product Data' that identifies the product
- Properties are the concepts that characterise the product. E.g. Shape, structure, structural behaviour, material type.
- Representations of those Properties, which can also be used to represent things other than product

  e.g. geometry can represent the shape of a plane, the path of a space shuttle, or the border of a drawing.

  The choice of how product shape is represented is an industry decision; for example, in theory you could represent the shape for manufacture by a finite element model.
- Presentation data which contains no Product information but defines how information should be displayed on paper, screen etc.

6.2 Product and Properties

Properties are the concepts that characterise a thing or a product. E.g. Shape, structure, thermal behaviour, material type. The picture above implies that Properties only characterise a

Product. This is not the complete picture, within STEP we need to be able to assign Properties to other things than just Products.

Consider for instance the behaviour of a product in some environment. The behaviour of the product will be dependent on its environment.

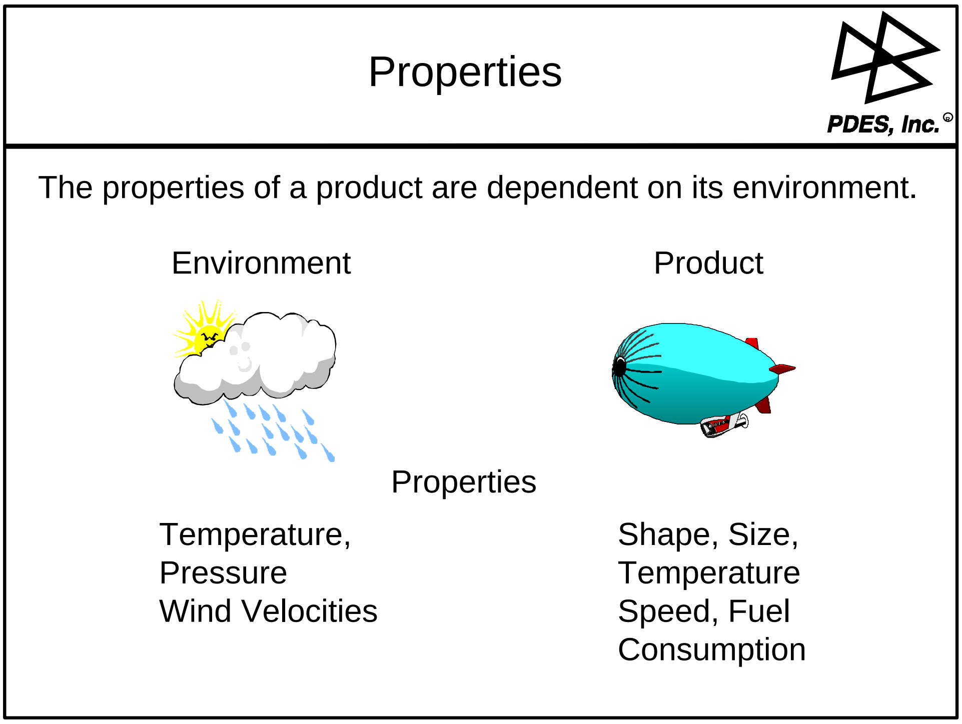


Figure 18 - Properties

Even for a simple mechanical product it shape (and size) will probably be dependent on the temperature of the environment. As the temperature increases the product will expand or change in some other way. Whether this is important will depend on the type of product.

When the shape of a product is exchanged then the condition at which this shape is valid should also be supplied.

Both the Product and the Environment have properties that need to be understood to enable the behaviour of a product to be predicted.

6.3 *Different Viewpoints*

How you describe an object (and what you call it) often varies depending upon your particular viewpoint. For instance a block of metal would be

- a product to the company selling it
- material to a company making something else from it

In addition, the information model could be different depending on the viewpoint.

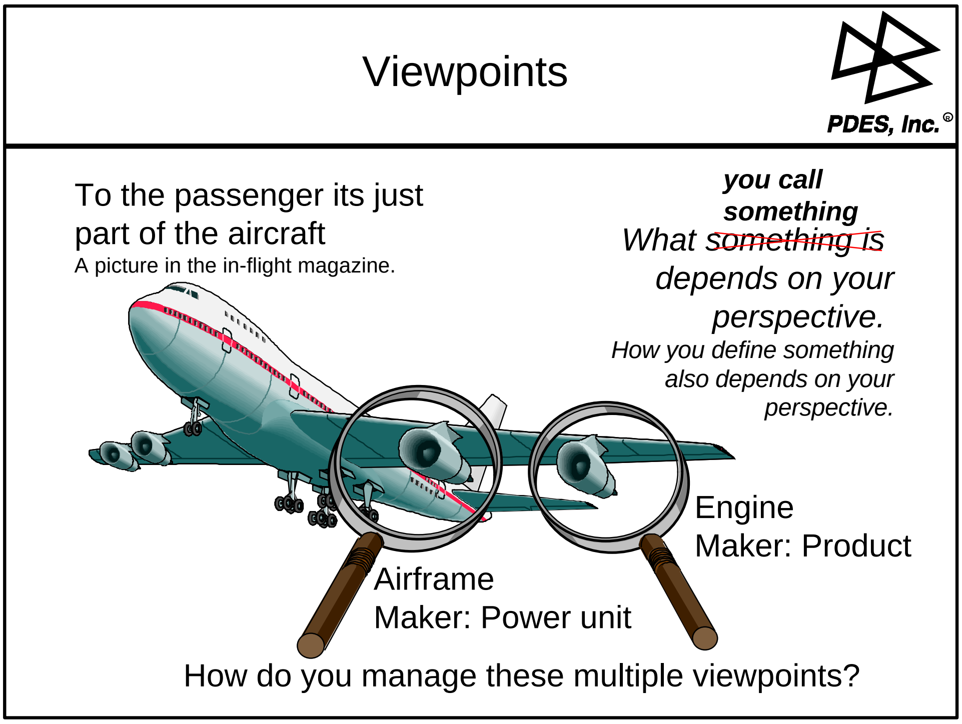


Figure 19 - Viewpoints

STEP needs to be able to handle these different viewpoints. Two of these alternate views are described in the next two sections.

6.4 *Means and Product*

Looking at the Means for the Product Life Cycle processes we see that the factories that design, make and operate/support the products are products in their own right. Someone has designed and built them and they are then operated and supported. The factories consist of many items:

- Facilities, Buildings
- Materials
- Tools
- People
- The knowledge gained from previous work, process experience and know-how
- Etc.

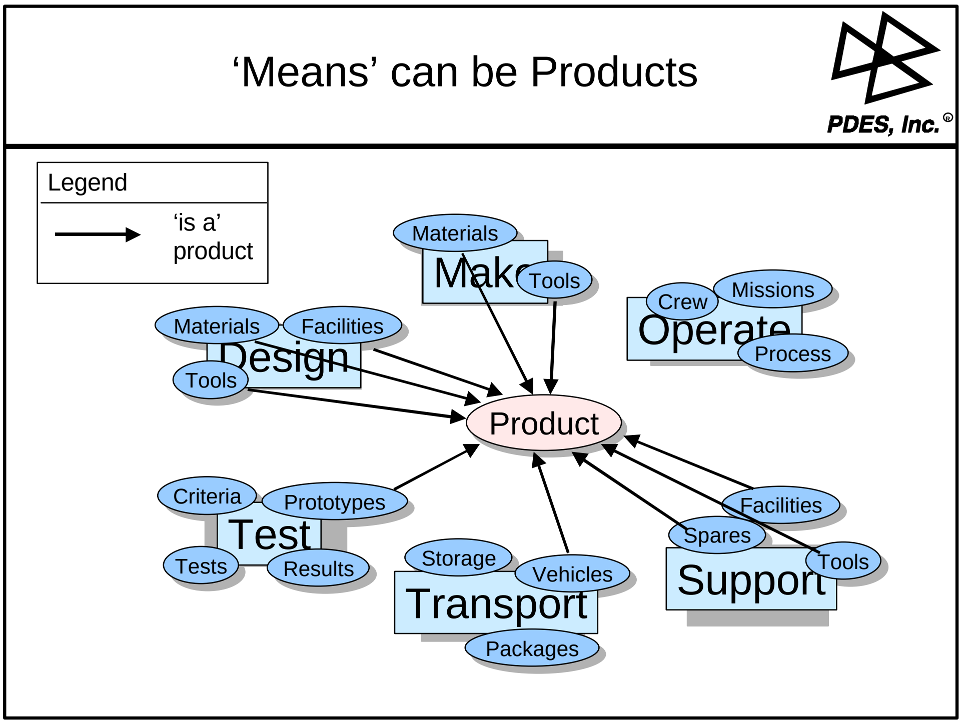


Figure 20 - Means can be Products

There are at least two viewpoints that can be considered when creating information models of these areas: -

1. The first viewpoint is to describe the items from within the Factories. For instance, within the Make Factory there are items such as Materials, Tools.
2. The second viewpoint is to consider these items as just products. All of the items are products in there own right and hence will go through (are within) their own 'product life-cycle'. This is shown by the 'is a' relationship to Product. The information models for the general product can then be used for these 'Means'.

6.5 Classification and Typical Configuration

There is a need within specific industries to model and exchange industry or product specific information. While a full survey has not been undertaken as yet, there are some concepts that can be modelled.

'Is a type of' - the classification of different types of product

'Consists of' - the specification of the composition of a product. **Note:** that there may be alternative or multiple ways for the decomposition of a product.

This second concept can be separated into two.

'Actually Consist of' - the specification of how a particular product is made up.

'Typically Consists of' - the specification of what a typical product is composed of. E.g. ships typically have a hull, engine etc.

Since all of the concepts being modelled are themselves products they have a 'is a' relationship to Product.

There are two approaches to modelling the above relationships. Take for example the 'consists of' relationship. This can be modelled either specifically or generically.

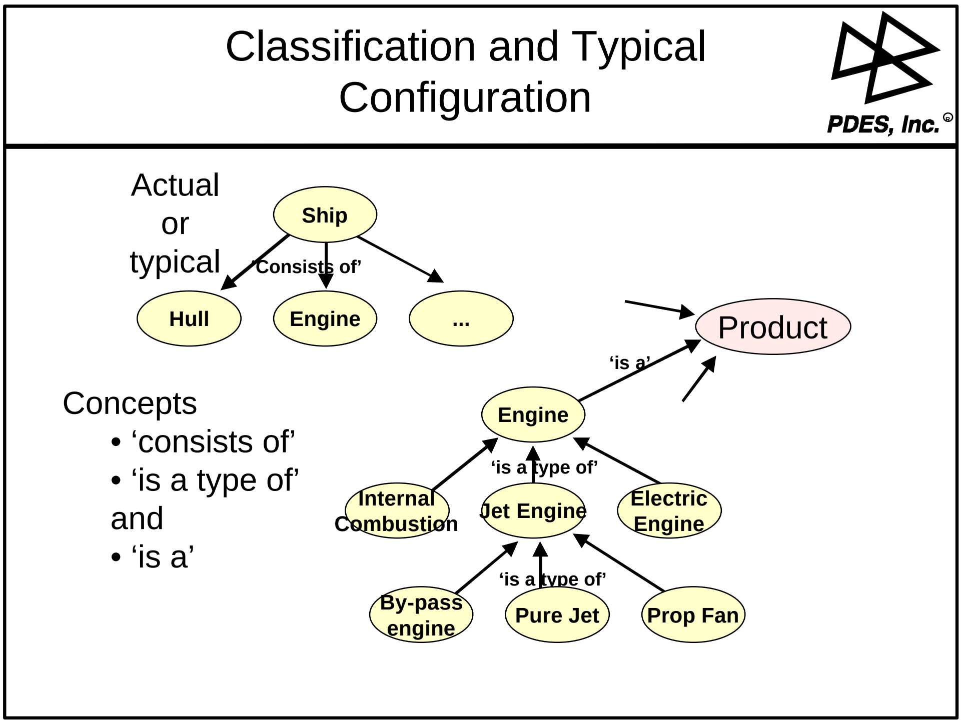


Figure 21 - Classification and Typical Configuration

Specifically

The data model is similar to the picture above and has specific entities (or objects) such as 'ship', 'hull', etc. that describe the way a ship is made up.

Generically

A generic model would have entities like 'product' and a general relationship that allows products to consist of other products. The specific information about ships would then be instances that populate this model.

When looking at the IIM categories it can be seen that the specific model would be categorised as an Industry specific concept. The generic model would have constructs in the product and/or item categories.

It is in fact valid to use either of these approaches, the best option depending on the use to which the model will be put.

6.6 Classification of Industries

Previous sections have discussed the classification of products and the relationship of different instances of the IPLC as you move up and down the supply chain. Reference 4 outlines similar issues with the supply chain. The diagram below, from this document, describes the major relationships of the supply chain from a cross industry viewpoint and provides a classification of industries (and hence of products). This compliments the more detailed view from the previous section.

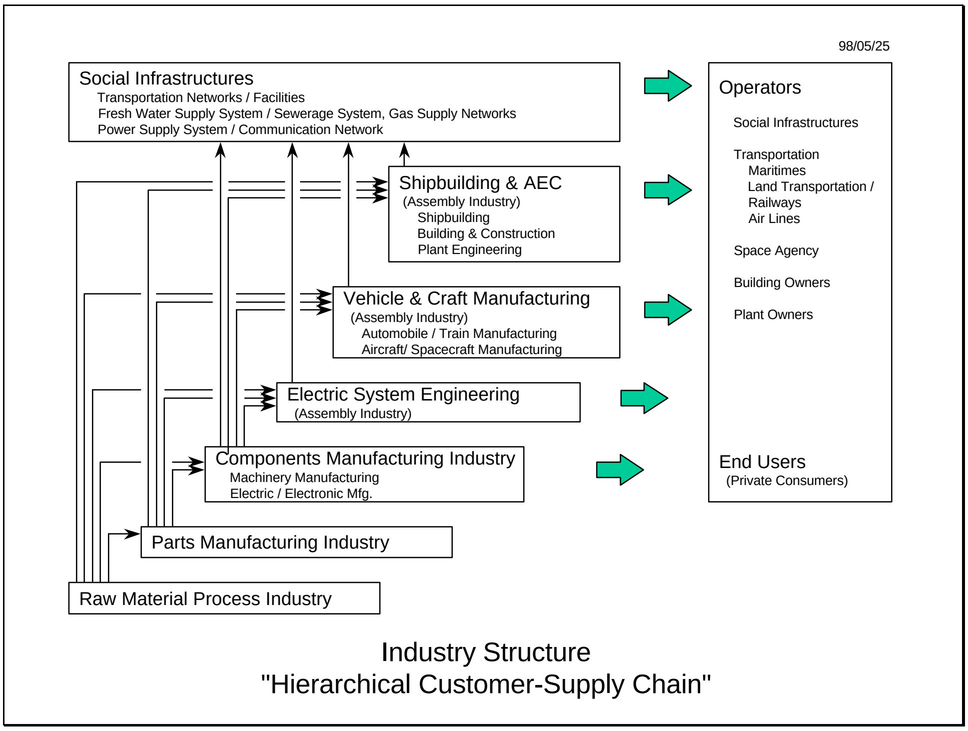


Figure 22 - Classification of Industries

6.7 Classification and Properties

To set up collaboration between companies, industry needs to agree what properties of a product are important and are to be exchanged (and then which representations are to be used).

In a previous section the concept of classification of products was discussed. The EXPRESS-G diagram below shows one method of modelling this concept.

Items that have the same characteristics (types of properties) can be classified into a **Class of Item** by the **Classification of Item**. For instance a particular ship could by classified as a Ship. It is useful to share this information as it describes what the product is.

The Properties that are relevant about a product can also be linked to this classification. (**Class of Item**). For instance, electrical properties are of interest if the product is a video recorder but probably not of interest if the product is a chair**. Characteristic Properties of a Class** allows this information to be held. It would allow electrical properties to be linked to the class of electric product but not to the class of chair.

It is these properties and their representations that industry will exchange. To enable exchange industry must agree the properties that are to be exchanged and hence must share this classification information.

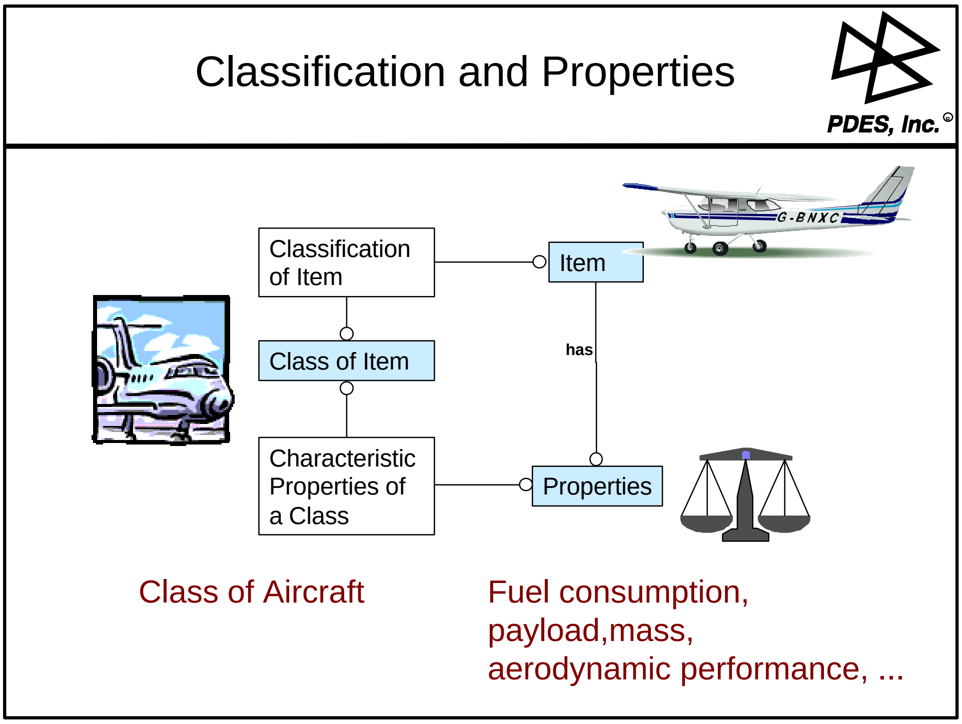


Figure 23 - Classification and Properties

6.8 Relationships between the IPLC Information Flows

It is the information flows in the IPLC that industry will wish to exchange and share between companies. When sharing this information, the relationship between them is also very important. There are some major relationships between the information flows in the IPLC that need to be capable of being shared. This section tries to describe some of these major relationships.

Two important ones are shown in the following diagram.

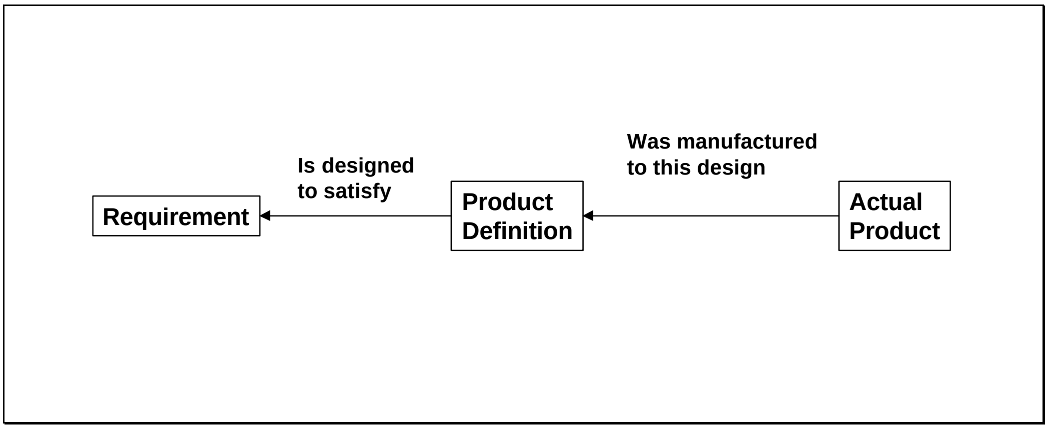


Figure 24 - Relationship between IPLC Information Flows

Note that these relationships may seem vague. It is always possible to say that the Product Definition satisfies the Requirement. It was intended that it should but the Design process may not have completely achieved that goal. It is however possible to say that it was designed to satisfy the Requirement. A more general way of expressing this is to say the Design process had the Requirements as a constraint and it produced this Product Definition. Only by comparing the Product Definition with the Requirement is it possible to say whether the intent was achieved.

These are specific examples and they do not cover the complete range of relationships that could be required. To generalise this we need to look at the business process that created the relationship between the various information types.

The next diagram shows the IDEF0 notation for a process and a data model (in EXPRESS-G notation) that relates the information flows with each other via the process.

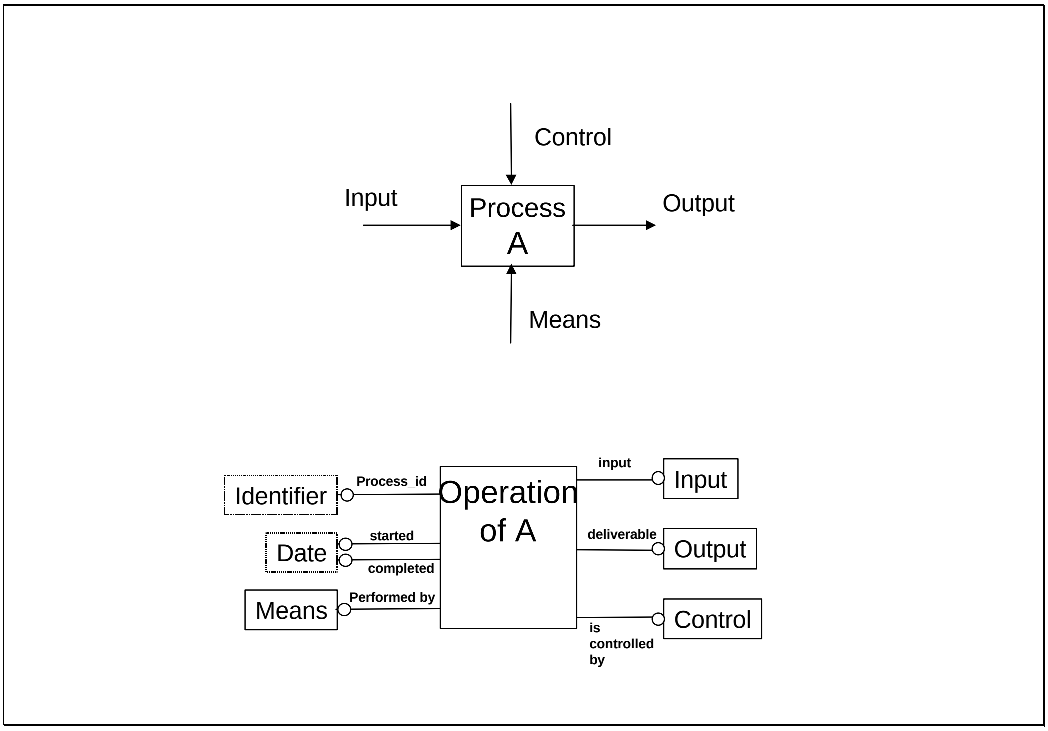


Figure 25 - Relationship between IDEF0 Flows

Applying the concept above to the IPLC processes gives the diagram below.

- The individual activities or processes in the IPLC are subtypes of a general **Activity** entity. The **Activity** is identified and can have start and end dates recorded.
- The **Activity** uses an **Item** as an input and produces an item as an output. The **Item** has a number of subtypes, which are the information flows in the IPLC.
- The **Requirement** is a control or constraint on the **Concept** and **Design** activities.
- The **Product Definition** is a control on the **Make, Operate, Support** and **Dispose** activities.
- The Activity is carried out by the means, which from the IFM is the Concept, Design, Make etc Factories. These are roles that a Factory plays and hence the means is should as **Factory**. Since **Factory** is an actual real object it is shown as a subtype of Actual **Product**.
- **Business Data** is shown as a control on all of the activities.
- **Factory Capability** is a control on the **Concept** and **Design** processes.

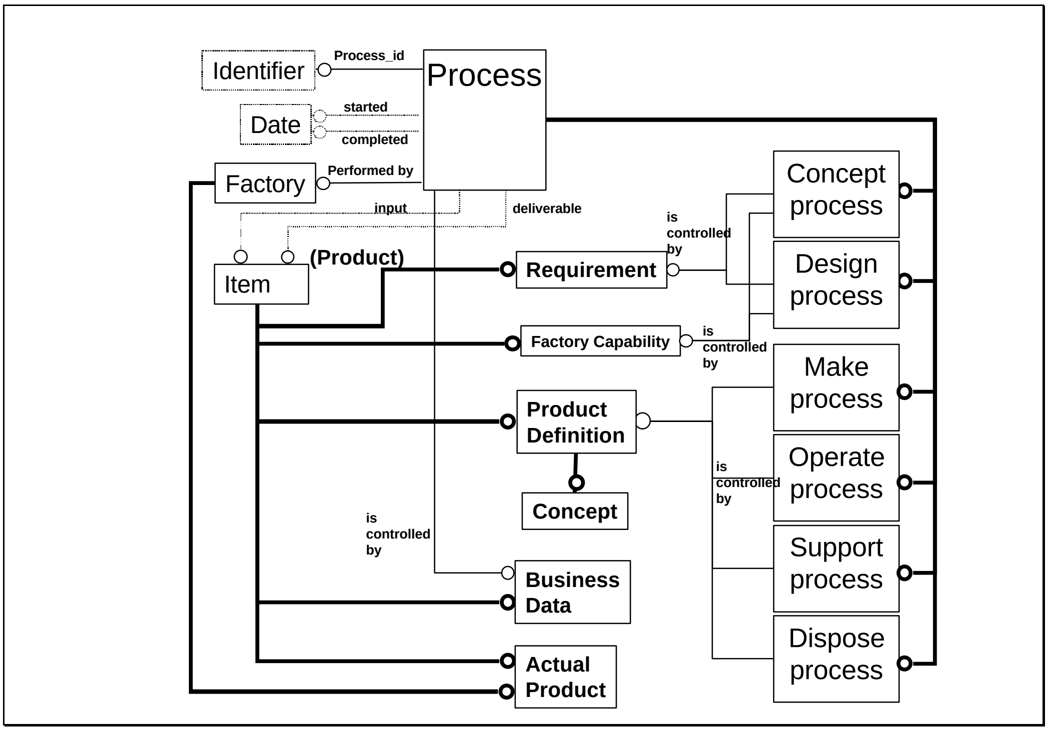


Figure 26 - IPLC Information Flow Relationships

7. Mapping Concepts onto the IIM

The IIM is derived from the Idealised Product Life Cycle together with the concepts discussed in the previous section. This section takes some concepts used within STEP and shows how they map onto the IIM Categories.

It is realised that not all the concepts within STEP can be mapped to the IIM categories. Later sections discuss which STEP concepts can be mapped to the IIM and which cannot be mapped.

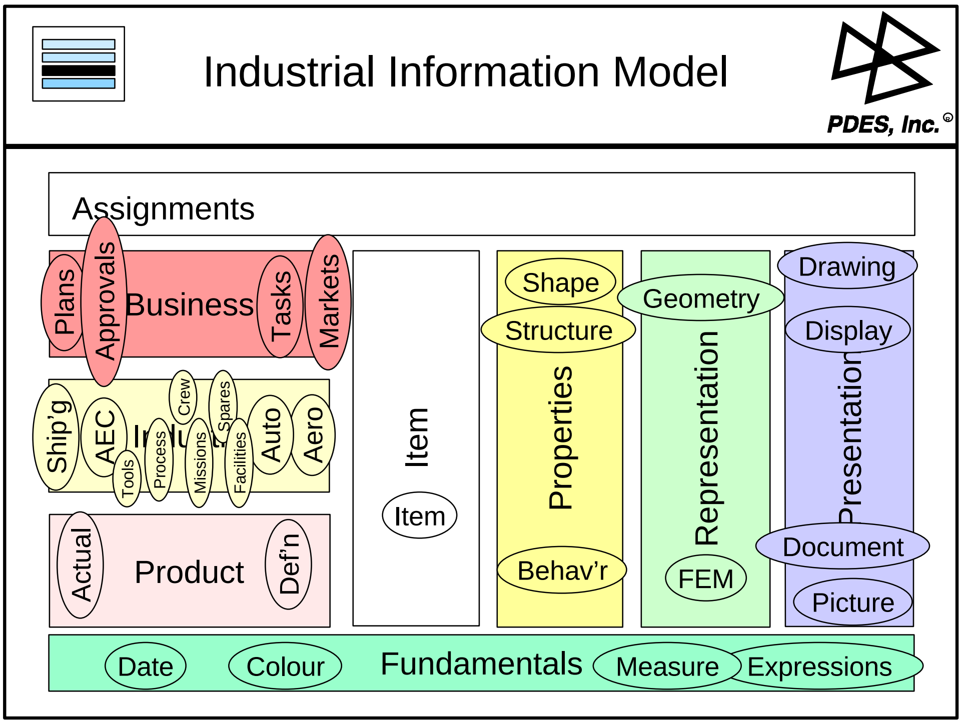


Figure 27 - Mapping Concepts onto the IIM

This picture shows how some lower level concepts map onto this view of Industrial Information.

Description of categories

7.1 Fundamentals

These are fundamental concepts that:

- Are very general in nature
- Can be used by modules in any of the other categories
- Could in principle be used independently of STEP

Examples: Date, Measures and Units

7.2 Business

These are concepts concerned with the operation of and control exerted by business.

The links between modules in this category and the product information will be to record the control that business management had on aspects of the life cycle of the product. For example this category would include Project Management, Business Planning, and Purchasing.

Examples: Project Identification, Organisation and Contract

7.3 Industry

This category covers product concepts that are specific to a particular industry or product type.

Examples: Ship, Plane and Manufactured Product

7.4 Product

This category covers concepts that are characteristic of all Products; it includes the identification of both Product Definitions and Actual Products.

Examples: Product Identification

7.5 Item

Item provides the link between the specific concepts within Product and Industry and the Properties of these items.

7.6 Properties

Properties are the concepts that characterise a thing or a product. E.g. Shape, structure, thermal behaviour, material type.

7.7 Representation

Concepts that are used to represent attributes, properties or characteristics of a product but could be used for other purposes. This includes concepts such as

- Geometry that can represent the shape of a product
- Finite elements that can represent both the shape and behaviour of a product
- Bills of Materials or Product Structure Trees that can be used to represent the structure of a product

7.8 Presentation

Concepts necessary to create a presentation of product information through some form of sensory method. The sensory methods would include visual, tactile, auditory, and olfactory.

These concepts could be used to present information other than product information, but in the context of STEP they are only meaningful if associated with product information directly or via a representation of product information.

Examples: Surface Appearance, Annotation, Drawing, Document

7.9 Assignments

Assignments contain the concepts that allow the others to be linked together to satisfy an industrial need. For instance, linking a Geometry representation to the Shape property. These concepts are needed to allow reuse of concepts and to allow industry to choose the appropriate combinations. For instance Geometry can be used for more than just Shape property and which geometric representation is decided by industry.

8. Application Modules

The concept of an Application Module is being used within STEP to modularise the standard into reusable parts. These modules will be used within Application Protocols to define the exchange standards for a particular application context.

8.1 Types of Module

Application Modules will exist in a number of layers from very generic modules to very application context specific modules. Each module will define an information model for one or more concepts. Where they require concepts already defined in other modules they will 'use' or link to those other modules. For instance an Approvals module may need a Date Time module. They form a directed acyclic graph, which is illustrated in the following figure. This shows the layers of modules.

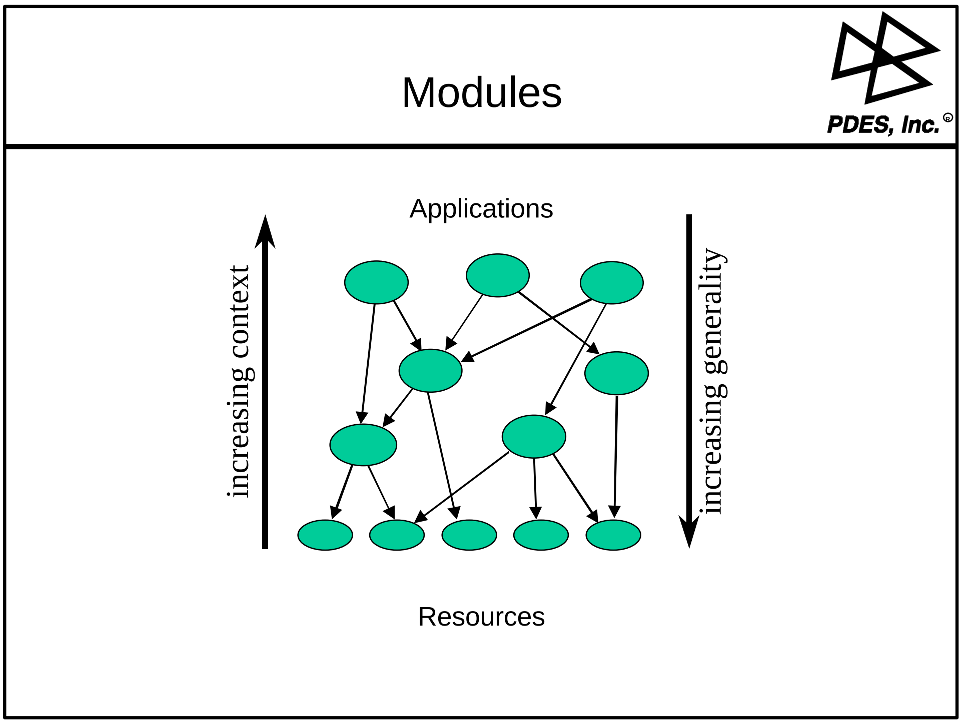


Figure 28 - Layers of Modules

The notation used in the diagram is that the arrow goes from

- the AM that uses the concepts defined in another AM

to

- the AM that defines those concepts.

There will be a number of different types of relationships between AMs but there are two fundamental types, which will be seen in the following sections.

- Where one AM is a specialisation of another AM
- Where one AM is defining a usage of another concept (requires), this can either be a mandatory or an optional relationship.

8.2 Planning Diagrams.

The diagram shown here suggests a notation that can be used to show the above types of relationship. This type of diagram can be used to plan a set of modules and the relationships between them prior to defining the detail of each module. This notation is used in subsequent sections of this paper.

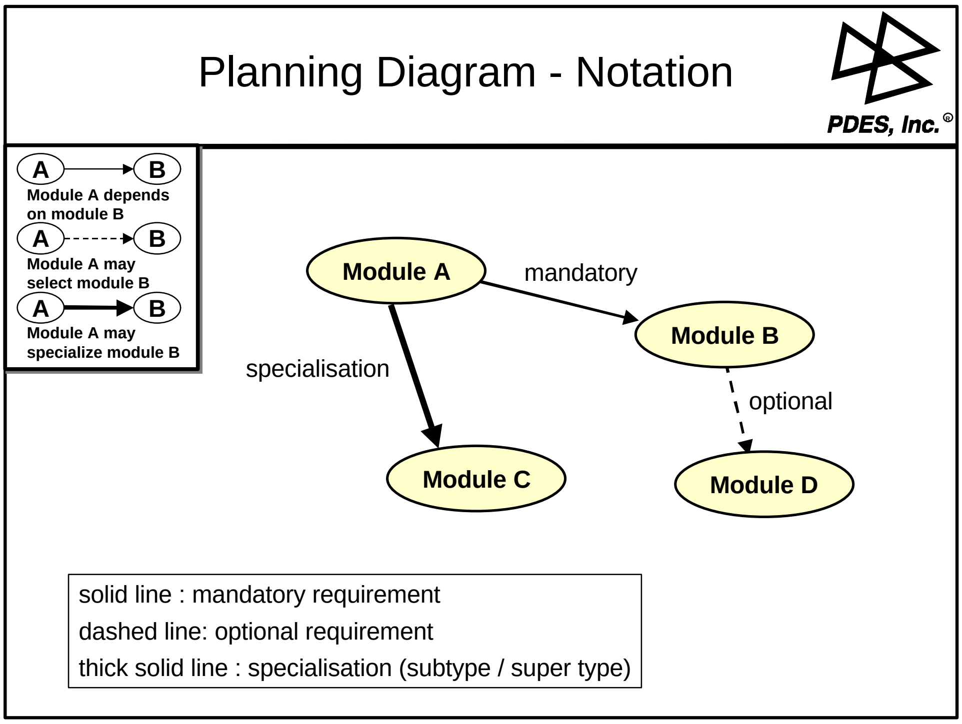


Figure 29 - Planning Diagram - Notation

8.3 Layers of Modules

It can be seen in the section 'Mapping Concepts onto the IIM' on Page 33 that it is possible to map elementary industry concepts onto the IIM. The IIM however does not allow us to categorise all the Application Modules that will be created. As AMs are combined they will form higher level modules that come closer to satisfying particular exchange requirements. AMs will then be combined into Application Protocols that industry will use to exchange information. These AMs will naturally span many of the IIM categories and can be mapped into the High Level AM category of the IFM. The IIM will therefore only be useful in categorising a certain low level of fundamental modules or concepts.

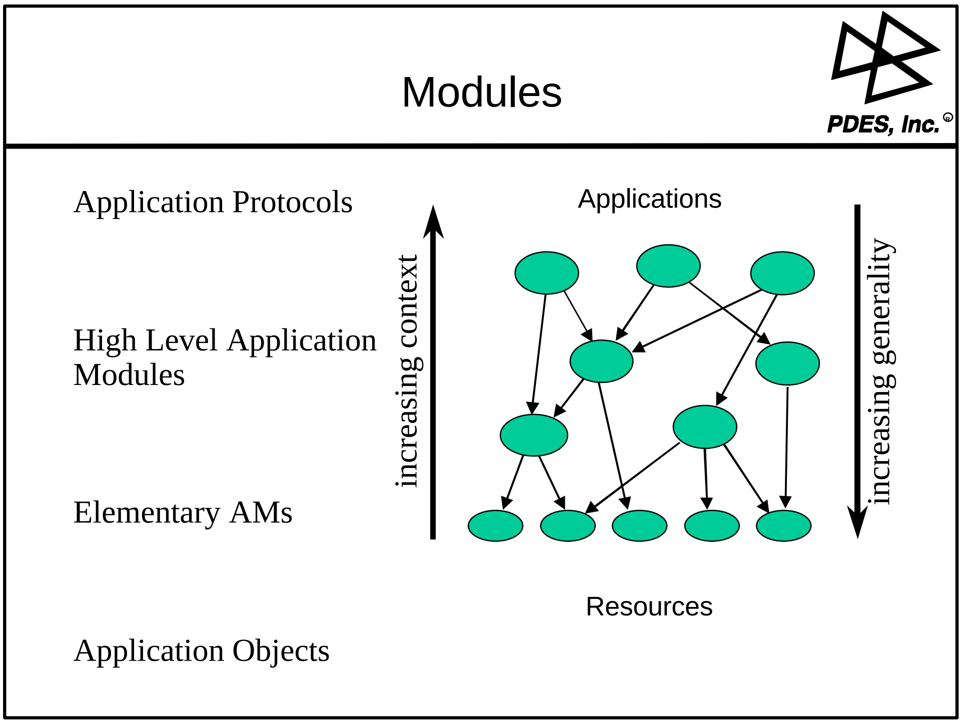


Figure 30 - Types of Module

8.4 Positioning Application Modules on the IIM

While all the implications of using Application Modules within STEP are not understood, it is believed that the lower layers of AM should map onto the IIM.

For the standard to be consistent and to allow reuse of Application Modules these lower layers of AMs must be positioned or scoped within the overall structure of the IIM.

There will also be basic relationships that link the modules together: -

- Some of these will be fundamental truths, for example a product has one or more product definitions
- Others will be design decisions, for example, product shape is represented by a geometric model (it could be represented by a drawing, and there are alternative geometric models).

The following diagram describes how the identification of various items could be modelled.

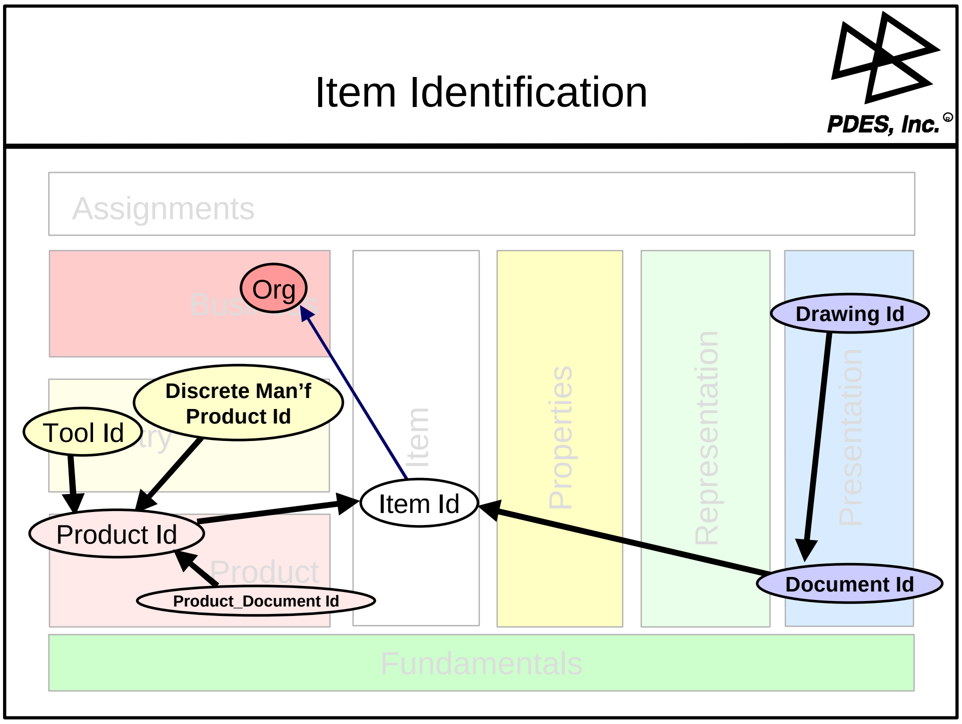


Figure 31 - Item Identification

An AM (**Item Id**) is defined to cover the identification of any generic thing or item. As the scope of this could be wider than STEP this is positioned in the Fundamental category.

Product ID: is scoped to apply to any type of Product.

Discrete Manufactured Product Id: apply to products that are being manufactured and can be identified by a part number. This is therefore a product or industry specific concept.

Tool Id: within the Make Factory a manufacturing tool name or number will identify tools, this is Industry specific. Since this is still a product it can use **Product Id**.

Document: this is a presentation of information in a human readable form. Documents can be used to present virtually any information and hence it uses **Item Id**. If it had linked to **Product Id** then this AM could only be used for Documents that are also products. This does not preclude the possibility of other relationships between Document and Product that define the product information that can be presented in a document. Indeed you would expect this in any PDM schema. It is also true that documents often are part of a delivered product, for instance the Operators or owners manual supplied with a product. There may be a need to have two modules for **Document**, **Product_Document** and **Document.**

Uniqueness of Identification: Identification of an item needs to be unique, there are a number of ways to satisfy this requirement. One could enforce a world wide naming convention, this is only practical for certain things like standards. It is not practical for all products. Since naming conventions are usually unique with an organisation the **Item Id** uses the **Org AM**. **Item Id** only has to be unique within Organisation.

9. Defining a Backbone of Application Modules

The following diagram outlines how a number of the core concepts relate to each other.

It is believed that these concepts will be defined in Application Modules and some subset of them will appear in most if not all Application Protocols. This core of concepts would therefore form a **Backbone** underlying Product Model Data.

It is also believed that these Backbone concepts can be defined so that they are applicable to most industries.

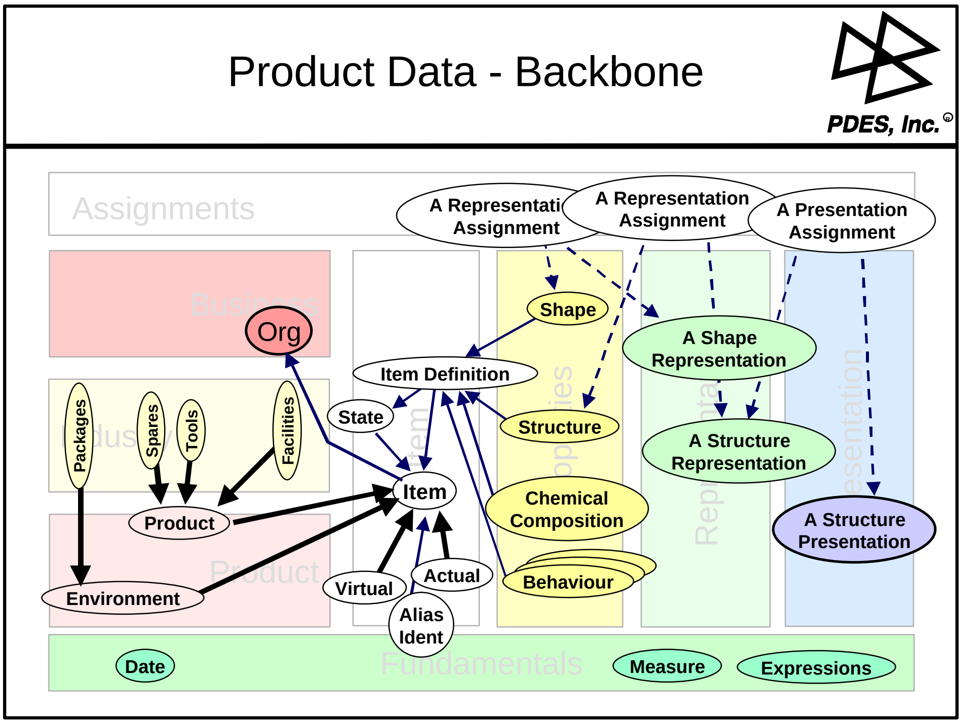


Figure 32 - Product Data - Backbone

The diagram is centred on the concept of an **item**. It shows that any thing or **item** can have a definition (**item definition**) and that definitions can have **properties.**

- The **properties** can be many and varied. The ones shown are **shape, chemical composition, structure** and **behaviour**, which is used as generic term for the various types of behaviour.
- A **product** is itself an **item** and hence can have a **definition** and **properties**.
- The **environment** that a **product** is subjected to is also an **item** and can have a **definition** and **properties**. The **environment** is the collection of conditions (e.g. temperature, pressure, etc.) to which a product is subject, and hence the conditions at which the behaviour of a product exists. Some **products**, such as a jet engine, may have a major affect on the properties of its **environment**. A jet engine creates thrust by increasing the velocity of the surrounding air. This **environment** has properties, chemical composition, temperature, pressure, and velocity.
- **Properties** such as **Shape** (or **Structure**) can be represented in alternative ways. This diagram shows **Shape** being linked to a **Shape Representation**. This could be some

geometric definition. Note the way it is linked. Neither the **representation** nor the **shape** concepts actually know the other exists. Hence a third concept links these two together. In effect this is a design decision. Any industry deciding to exchange the shape of products would need to agree the actual representation to be used and if a geometric one is chosen what class of geometric definition, wireframe, surface, solid etc.

- Other Properties (shown as Behaviour) will have alternative methods of representing them.
- **Presentation**. Some industries need to exchange definitions of how to display or present information. For instance, a Geometry representation may be linked to a **Presentation** module. In this example it may define how lines, surfaces etc are to be displayed. The **Presentation** is linked to the **representation** by an assignment because there may be alternate options.
- **State** allows the condition of the **Item** to be identified. An **Item** and its behaviour or **Properties** may well change depending on the **State** of the **Item**. For instance, the **Shape** of a parachute is quite different when it is packed compared with when it is being used.
- Information about an **Item** can be about a real or **actual item** of about a **virtual item**. In the Product life cycle there are two major information flows: - Product Definition, which is the design of a **Product** that could be made and Actual product, which is information about a **Product** that has been produced.
- The concepts of **Actual** and **Virtual** can also be used when describing then **Environment** the **Product** is operating in.
- The identification of an **Item** is only unique within an **Organisation**.

10. Positioning Application Modules on the IFM and into the Backbone

This section describes how various subjects can be mapped onto the IFM and proposes how they fit into the Backbone.

10.1 Materials

The current materials schema within STEP covers the properties or behaviour of a 'Material'. It is recognised that Material properties are also a property of a Product and that all 'engineering materials' are products. 'Material' does not have a separate existence. Material properties are a characteristic of a product just as its shape is.

Typical 'Material Properties' are: -

- Strength
- Hardness
- Fracture toughness

The Property values have to be associated with the conditions in which they are valid. As the values are often produced by testing samples of material the confidence in the values can vary, the Materials schema also allows quantitative and qualitative measures.

Having ascertained the properties of a material type the Design process will use this information to predict the likely behaviour (properties) of a product manufactured from that material type.

The following diagram puts some of these concepts into context.

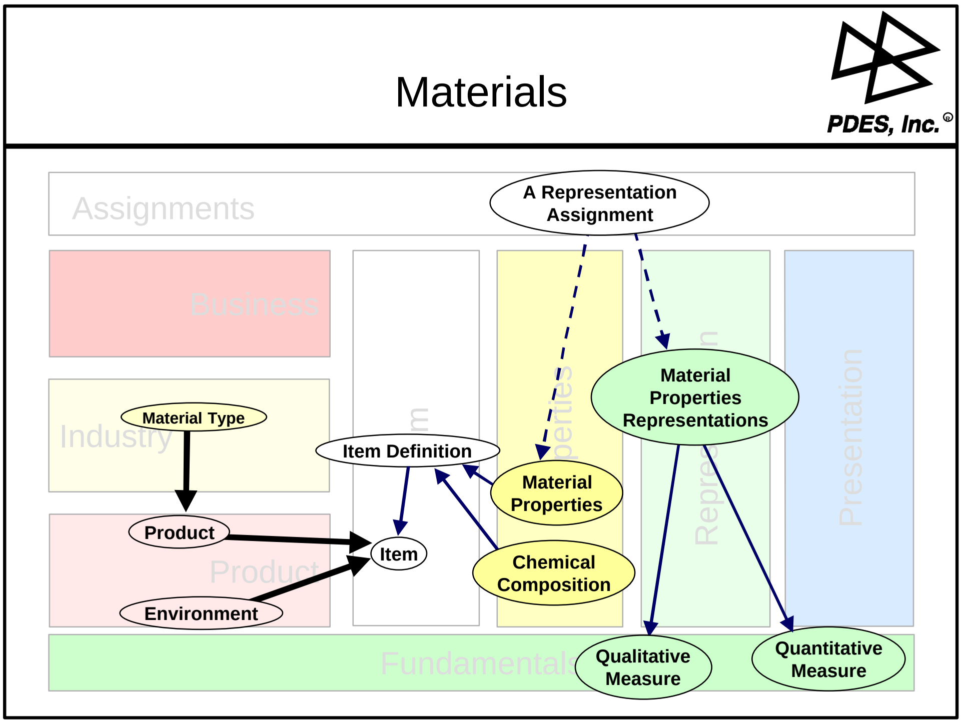


Figure 33 - Materials

10.2 Engineering Analysis

Engineering Analysis (EA) is the process of predicting the behaviour of a product and its environment. EA utilises many different numerical techniques to model the laws of physics and to solve those equations.

The types of behaviour that will be predicted is wide and includes Acoustics, Aerodynamics, Costs, Dynamics, Electrical and Mechanical Behaviour, Fatigue, Fluid Mechanics, Fracture, Fuel Efficiency, Heat Transfer, Hydraulics, Kinematics, Optics, Producibility, Stress, Structures, Thermodynamics, and Vibrations.

The analysis will use a representation of both the product and its environment and use a mathematical model to predict the behaviour of a set of the above properties, and hence a set of attribute values, temperature, pressure, changed shape of product, stress, etc. Most of these parameters are continuous functions that will vary by **spatial position**.

These concepts are illustrated in the Backbone diagram in section "Defining a Backbone of Application Modules" and in the following diagram.

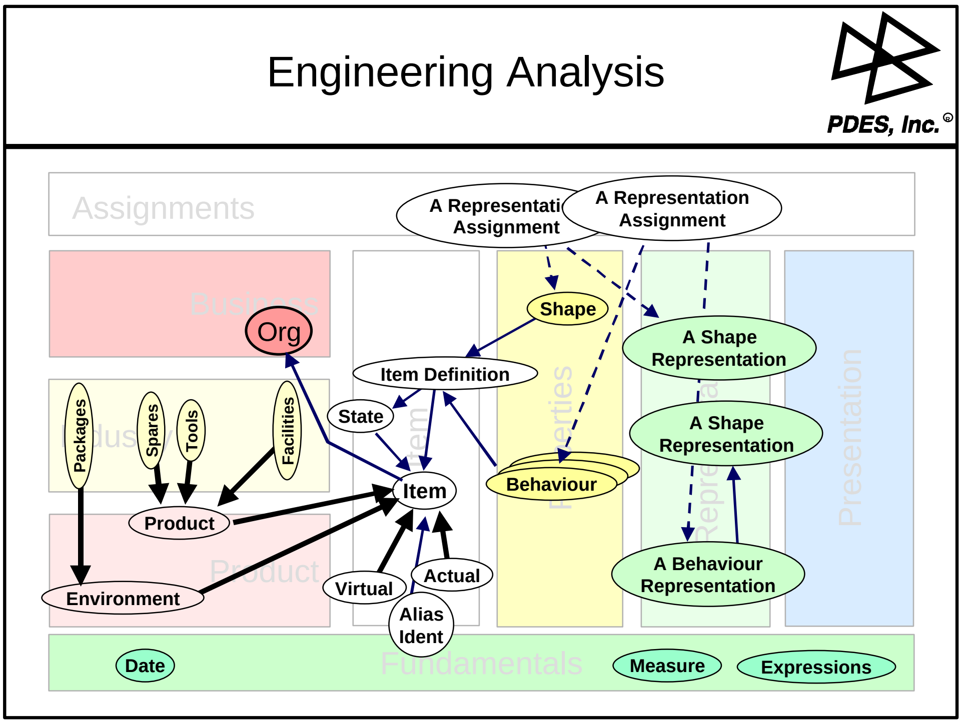


Figure 34 - Engineering Analysis

10.2.1 Relationship between Engineering Analysis and Materials

At some point in the Engineering Analysis process the properties of the product will be produced. These properties are in fact very similar if not identical to those considered within the Material property world. The manner in which the values where produced may well be different and hence the Representation may need to be different.

10.2.2 Other standards

Most industries exchange information about the properties or behaviour of a product in terms of attribute values. There are some industries that exchange this information in the form of a computer model that will simulate the product behaviour when given the environment.

It is an open question as to whether STEP should address this second method but it should at least allow this type of information to be linked into the STEP model.

10.3 BLOBs and Files

There will be occasions where data is NOT held in a STEP structure and STEP needs to be able to at least reference the information. This information could either be held in a **digital** format or as a **hardcopy**. If the information is held digitally then it would also be possible for STEP to include the information within a STEP exchange file.

Examples of this are: -

Documents are held in some proprietary format

Where the shape of a product is defined by a hardcopy drawing

Where the behaviour of a product is predicted by the use of computer software model

To handle this requirement two concepts would be required

BLOB - a binary large object, this is a digital set of information in a NON STEP format with identification of its format. This would be a representation that could be assigned to a particular property to enable the exchange of the object itself.

External object ID - this would be the identification of either a digital file or a hardcopy file when only the identification needs to be exchanged.

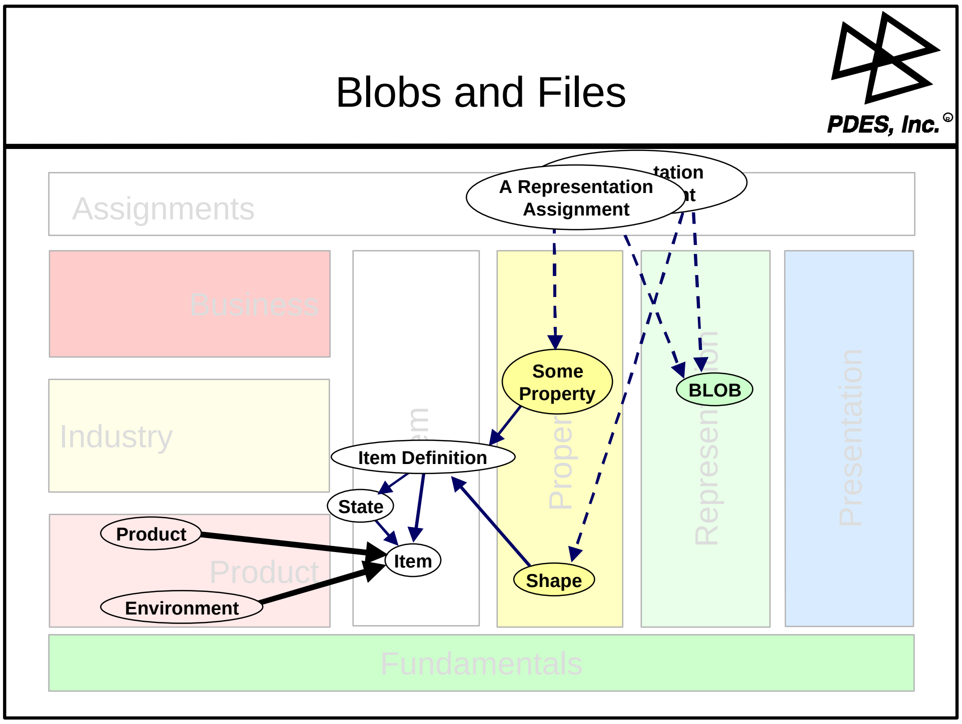


Figure 35 - Blobs and Files

Note: STEP contains Implementation Methods (Part 20 series) that map the Information Models to an Implementation Method, such as a Part 21 file. These concepts are different to the above but would be used to map either the BLOB or the External File ID to say a Part 21 file.

10.4 Logistics

Logistics is the science of the movement, supplying, maintenance and support of a Product. To carry out the support process there is a requirement to have available various types of information about: -

- The actual product that is to be maintained, for instance its configuration.
- The configurations that are allowed to be produced, the Product Definition.
- The facilities and their capabilities available within the Support Factory (the means for the Support process) to carry out the support process. This would normally be the actual Support Factory but where new facilities are being planned then this could include the Support Factory Definition, its design.
- To carry out the logistics process the location in the world of real items is required.

In the section "Interaction between Life Cycles" on page 22 it was shown that the same general information model should support the Capability of the Support Factory. To support the above some extensions to the Backbone will be required: -

- To describe the capabilities of the Support Factory a range of new Properties will be required; in the following diagram these are indicated by the group of properties shown as "Behaviour".
- To provide an industry understanding of what facilities are available some industry concepts will need to specialise concepts such as Product.
- To provide a Location property that allows the position in the world of a real object to be defined.

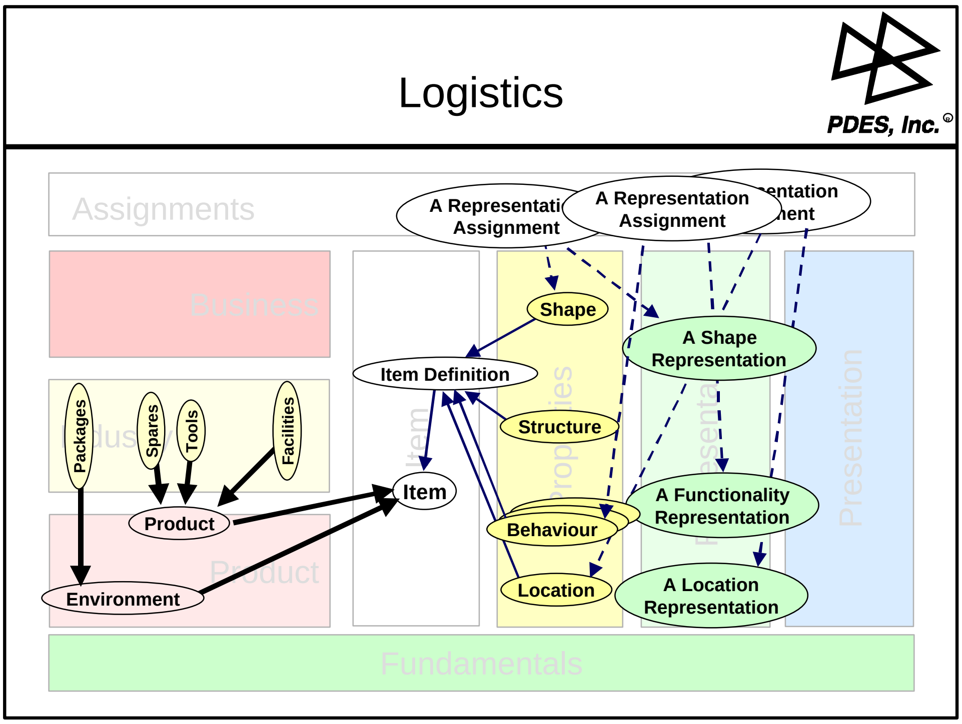


Figure 36 - Logistics

10.5 Product Data Management

A definition of how PDM fits into the IFM and the Backbone is awaiting a modular view of the PDM Schema.

10.6 Requirements

This area requires investigation to fully define how it relates to the other information flows. A general observation can be made that the Requirements entering the Product life cycle. They can specify values required, by the customer, for any of the information flows within the rest of the process.

For instance the Requirements could define: -

- Properties of the product being designed
- Requirements on the operation of the life cycle processes, how long the design should take, how easy the product can be maintained.
- How much the customer is willing to pay for the product.
- The number of products required.

10.7 Validation of data

For some types of representation it may be desirable when exchanging information to include addition data against which data translations can be validated.

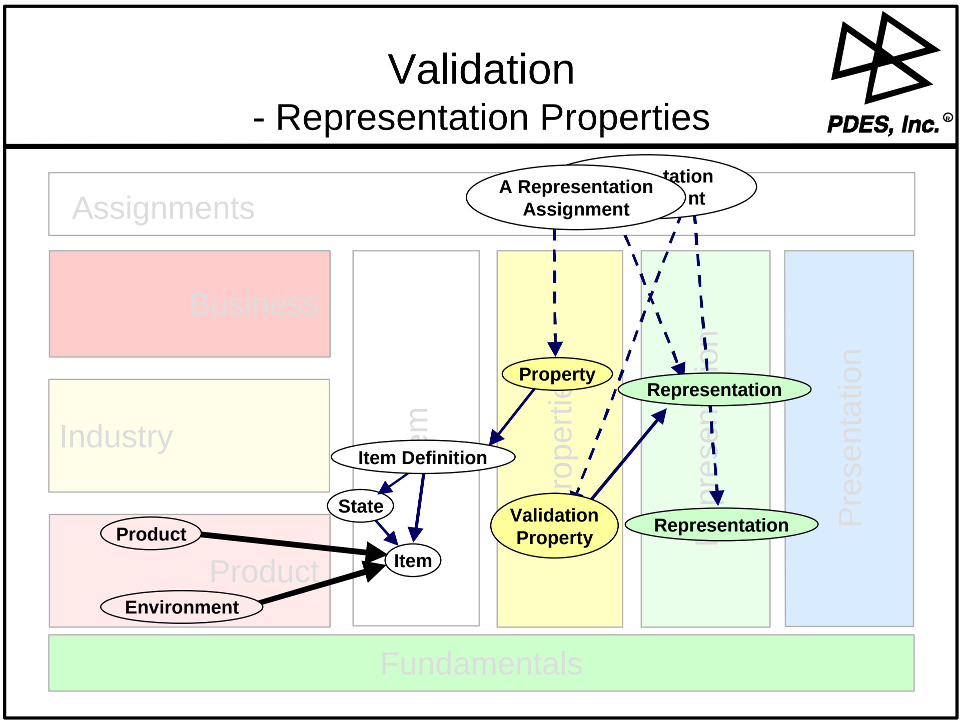


Figure 37 - Validation

For instance, when exchanging geometric solid models, the properties of the solid can be exchanged and these can be checked to validate that any geometric conversions have been carried out correctly.

These types of validation data should be specified as Properties of the Representation. They in turn have representations.

11. Guidelines

This section gives some guidelines regarding how both APs and AMs should fit together and fit into the IFM.

11.1 IPLC

The purpose of an Application Protocol is to support the exchange of information between a particular set of processes. For APs that deal with manufactured products it should be possible to define which information flows in the IPLC they support.

11.2 High Level Application Modules

Modules that link together concepts that span IIM categories should be placed in this category.

- Ideally, these modules should always use elementary modules.

11.3 IIM

This section gives some guidelines regarding the way the Elementary AMs should fit together. Since the concepts at this level are those that most Application Protocols will require, it is important that these AMs are created so that they are as **re-usable** as possible. The guidelines are aimed at achieving this objective.

- Any AM can call upon concepts in the Fundamental Category.

- An AM inherits the constraints from any other required modules (mandatory or specialisation relationships), for instance a module calling upon an Industry module becomes Industry specific itself.

- Any link between AMs in different categories should be carefully considered. The previous sections highlight some of the valid relationships.

- In general while a Property may have a Representation, which in turn may have a Presentation the actual way properties are represented and presented will be decided by particular industries. The AMs that specify these links between concepts will map into the Assignments section of the IIM.
- Much of STEP is concerned with properties of a product and its representation. A module should not contain both the Property and its Representation unless it is certain that there will only be one Representation for that Property.

- It is probably not appropriate for STEP to define full information models for the modules in the Business category but it should at least provide the appropriate linkage to these concepts.

- Only AMs within the Industry category can be industry or product specific. For instance if a particular industry requires a specific type of geometry then it should be defined as a reusable Representation. APs can then use it for that industry and it also allows other industries to use it if appropriate.

- To ensure reuse of modules, a module should not be aware of other modules that use or require it. You should apply the PINC principle. PINC: Principle of Independent Concepts. This is simply that concepts that are independent of each other should be modelled that way.

For instance geometry should not know what it is geometry of. Approvals should not know what it is approving. Going against this rule is similar to having a parts library where all the parts know where they are used in a product, e.g. the bolt knows which products it can be used in.

- AMs should not require other AMs in a recursive manner. In the following diagram one of the arrows is invalid. If the concepts are really that dependent on each other then they should be a single AM.

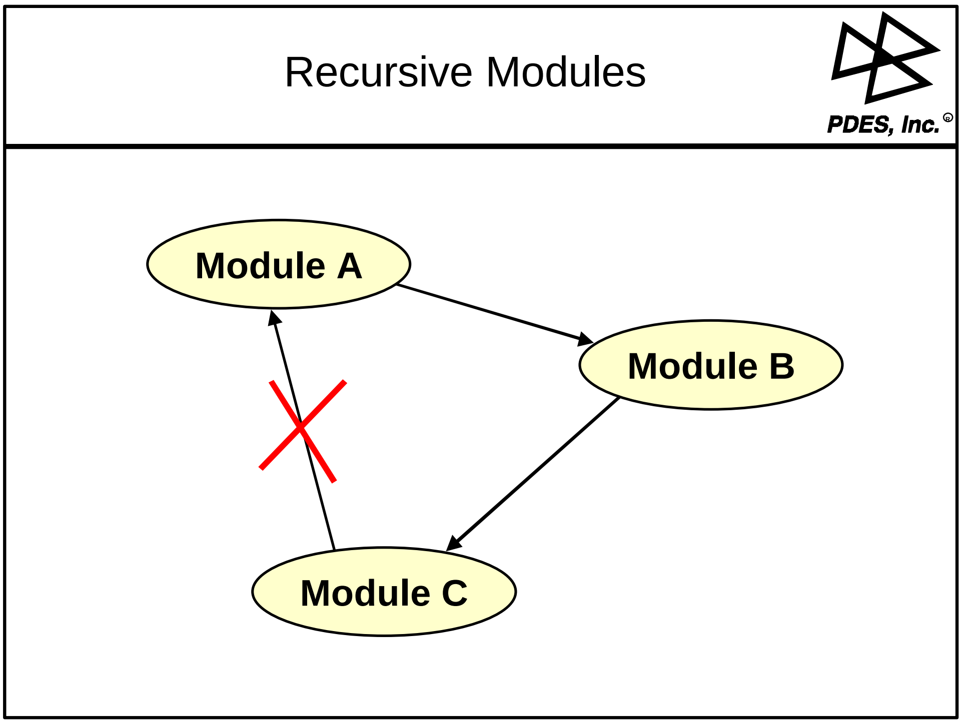


Figure 38 - Recursive Modules

12. Extending the Backbone to Support Multiple Industries

Any definition of the business requirements for data exchange will use a particular terminology depending on the author and their background. A conscience effort has been made to make the terminology in this paper as neutral as possible. This is of course extremely difficult if not impossible to do, however it should be possible for people from differing industries to map both their terminology and business processes onto this paper.

The concept of a Backbone of Application Modules that should be true for most industries has been described. The assumption behind this is that different industries are actually very similar once the different terminologies have been understood. If these similarities can be built upon then STEP will be more widely accepted and more quickly developed and implemented.

12.1 Testing the Model for Different Product Types

To achieve a Backbone of STEP Application Modules that support a wide range of industries we need to test the concepts against a suitable range of product types. One of the diagrams in Reference 4 contains a view of the types of industry that need to be considered and this is reproduced in section 'Classification of Industries' on page 28.

This provides a useful list of industry types and hence product types to test the backbone against: -

- Shipbuilding and AEC
- Vehicle and Craft Manufacturing
- Electrical System Engineering
- Components Manufacturing
- Parts Manufacturing
- Raw Material Process Industry.

In addition to this list we need to test that these concepts also support the life cycle of the Factories that create the products. The backbone should support

- the Design, Make, Operate, Support, and Dispose factories.

12.2 Extending Property Types and their Representations

Probably the main area of STEP that will continually be extended is that of Property types and their Representation.

As new products are developed new properties will be needed and some representation will be required.

A table, as below, could be used to record these new requirements for each new product type.

Some of these properties and representations will apply to a wide range of products and some will be specific to certain industries. (Generic versus industry specific).

Product Type	Property	Representation

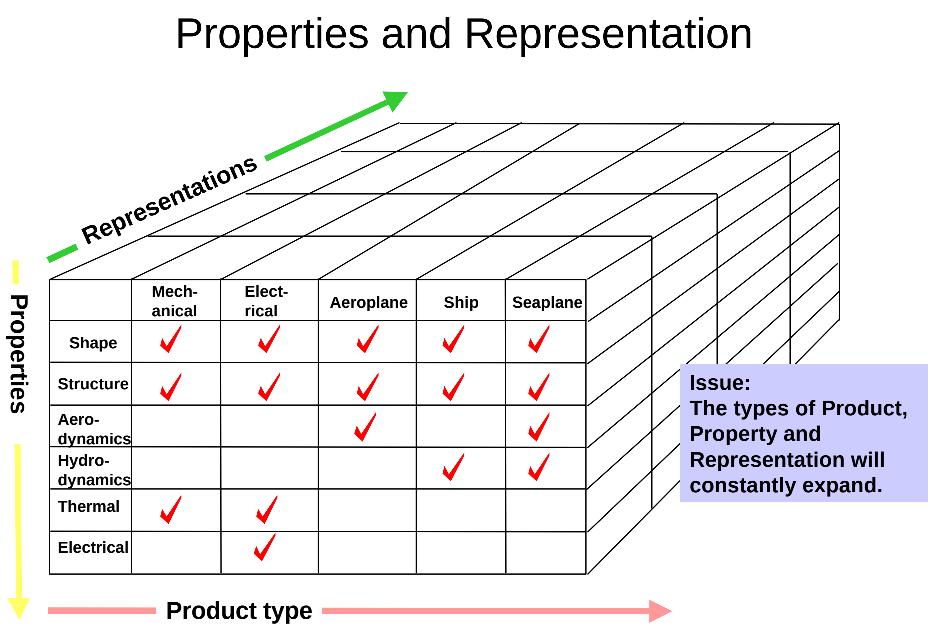


Figure 39 - Properties and Representation

13. Defining the Contents of the IPLC Information Flows - Example

To identify the Application Modules that will be required to support the various product types we need to decompose the information flows defined in the IPLC. This section is a **first attempt** to do this for a typical mechanical product, probably biased to an aerospace product.

This exercise needs to be repeated for the range of Product types outlined in section 'Testing the Model for Different Product Types'.

The diagrams all use EXPRESS-G notation.

13.1.1 Requirement

The Requirement consists of a set of constraints against either the properties of the product and / or the life cycle stages.

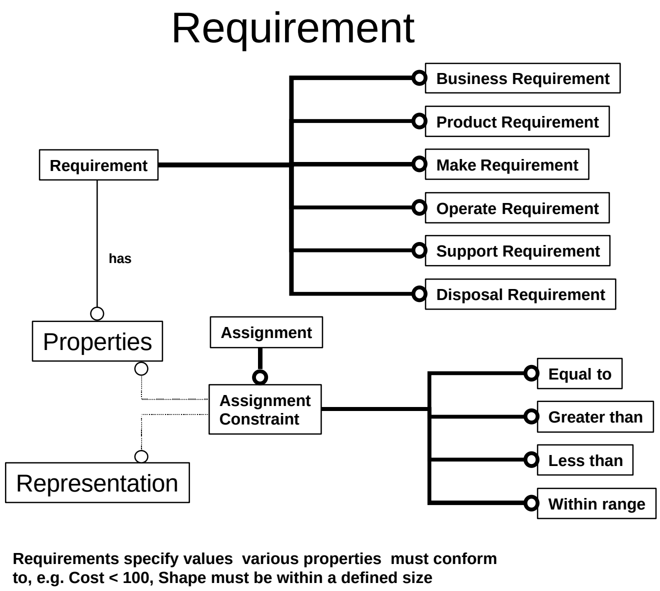


Figure 40 - Requirements

For example: -

I want a jet engine whose thrust is at least 30000 lbs. and whose weight is less than 10000 lbs and I want it delivered by dd/mm/yyyy.

This is of the form:

I want a product of class Jet Engine whose Properties are

Property	Assignment Constraint	Representation
Thrust	greater than	30,000 lbs.
Weight	less than	10,000 lbs.

The requirement on the Design and Make process is to deliver the first product by dd/mm/yyyy.

13.1.2 Product Definition

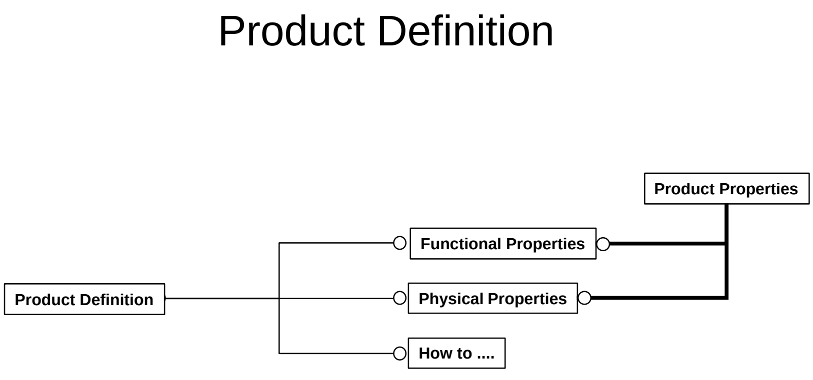


Figure 41 - Product Definition

The Product Definition consists of three parts

- functional definition and properties of the product
- physical definition and properties of the product

and

- any constraints the Design process wishes to place on the down stream processes (such as how to make or operate the product)

These parts are described further in subsequent sections.

13.1.3 Actual product

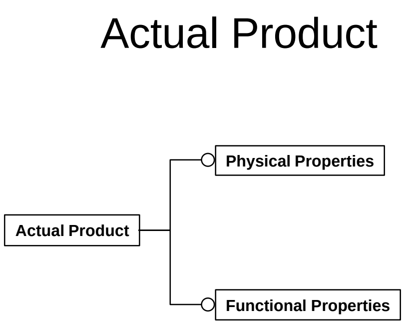


Figure 42 - Actual Product

The Actual Product consists of the Physical and Functional definition and properties of the product.

13.1.4 Functional Properties

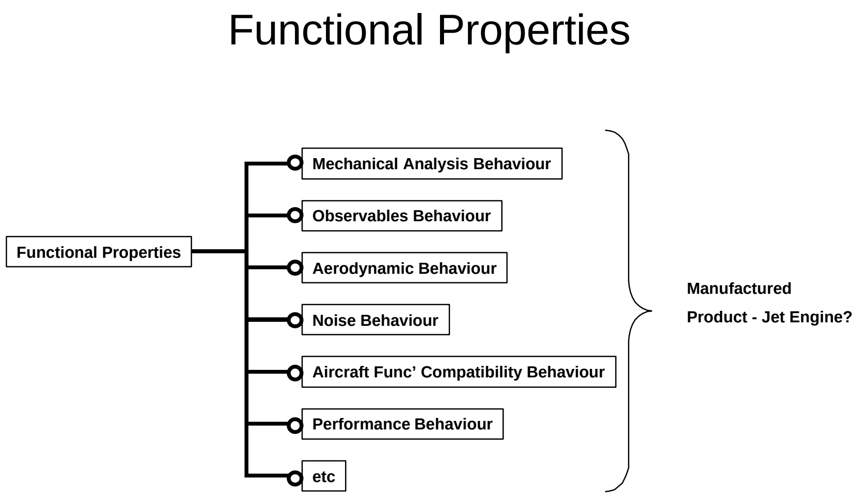


Figure 43 - Functional Properties

This is an example of some of the functional properties that would be important when the product is a jet engine. Similar lists could (and should) be created for the products of interest to each industry. This is an area the Engineering Analysis developments will detail.

13.1.5 Physical Properties

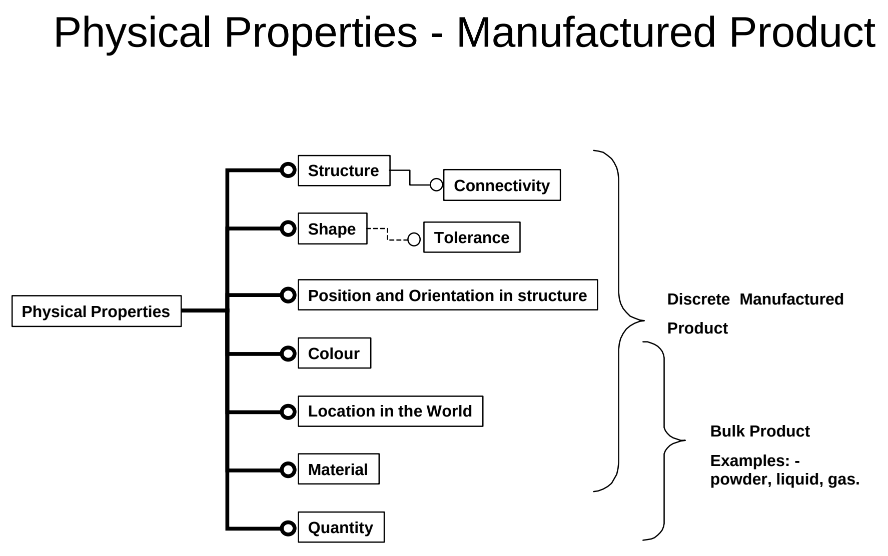


Figure 44 - Physical properties

This shows typical physical properties for manufactured products, which of course could be extended to cover other product types.

13.1.6 How to...

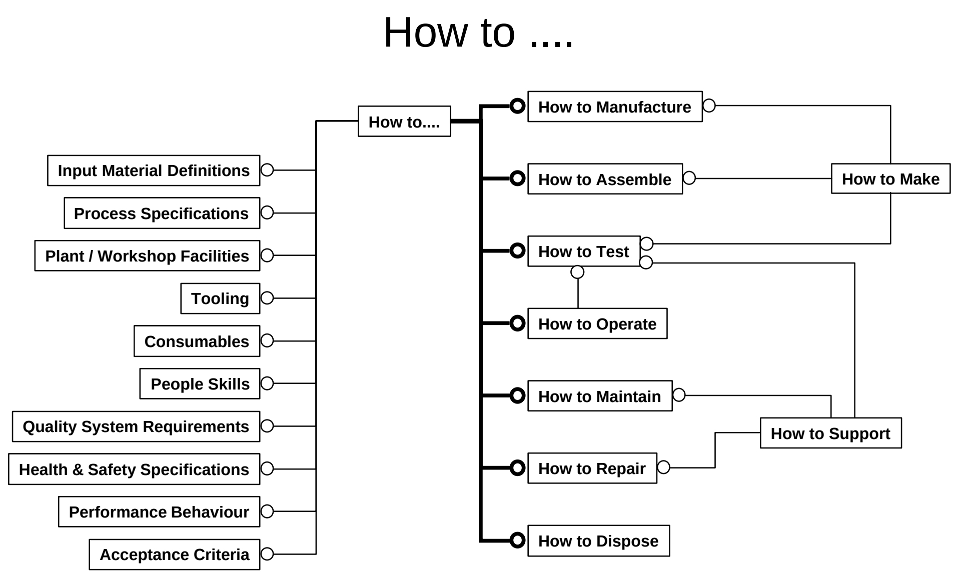


Figure 45 - How to...

This shows the type of information that could be used to constrain the various life cycle processes, again from the viewpoint of a mechanical or industrial product.

It should be noted that the items defined here are very similar to those defined under Business Data.

The Make process has effectively been decomposed into Assemble, Manufacture and Test and Support has been decomposed into Repair, Maintain and Test.

13.1.7 Business Data

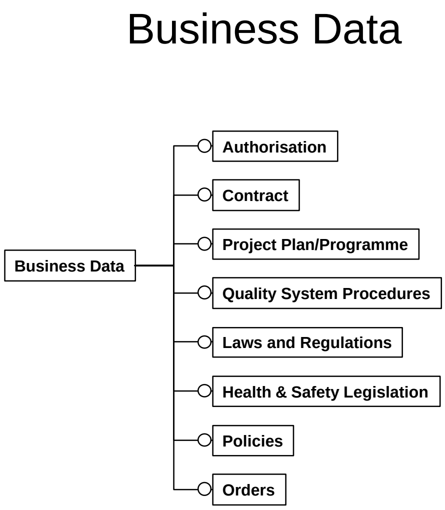


Figure 46 - Business Data

Business data is a constraint on all the life cycle processes and consists of a set of external influences on the processes.

13.1.8 Experience

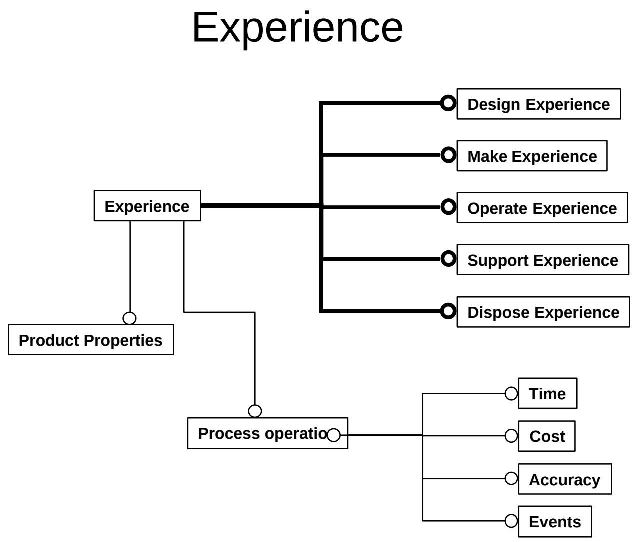


Figure 47 - Experience

The Experience (or feedback) defines how well the life cycle processes were operated and links to the properties of the products that were used or created. For instance the Make Experience would contain the operation of the Make process and the attributes of the products that were manufactured.

Appendix A - References

1. GPDM - Generic Product Data Model, William E Danner, Yuhwei Yang, Version 0.9 Draft 5 Jan 91

2. GEDM - Generic Enterprise Data Model, William E Danner, Yuhwei Yang, Version 0.2 Draft 5 Jan 91

3. Generic Product-Data Model Resources for STEP, William E Danner, Yuhwei Yang, Nigel Shaw, Version 0.3 Draft 1 Feb 91

4. Proposals for STEP/SC4 AP Framework and Related Recommendations - Working Draft 0.8A - Yoshiaki Ishikawa, IHI

5. AP Development Guidelines for Shipbuilding - ISO/TC184/WG3 N701

6. The nature of industrial data, ISO/TC184/SC4/WG10 N64, Draft 0.7, June 27, 1996

7. The Product Model - CALS Technical Goal, Forsvarets Materielverk (FMV) CALS Office, 1996

8. Product Life Cycle Support, Statement of Technical Requirements, John Dunford, November 1998
9. ISO/NWI 10303-MATINF - Material Properties Process Model, March 1998.

10. NISTIR 5939, Systems integration for Manufacturing Applications (SIMA) Reference Architecture Part 1: Activity Models, National Institute of Standards and Technology, (NIST)

Appendix B - Definitions

Actual Product: An instance of an actual physical product that could be sold to a customer.

Application Module (AM): a reusable collection of scope statement, information requirements, mappings and module interpreted model that supports a specific usage of product data across multiple application contexts.

Application Protocol (AP): a part of this International Standard that specifies an application interpreted model satisfying the scope and information requirements for a specific application.

Application: a group of one or more processes creating or using product data.

Assembly: a product that is decomposable into a set of components or other assemblies from the perspective of a specific application

Behaviour: a collection of related properties that describe how a Product reacts (with its environment). For instance the thermal behaviour of a Product.

Component: a product that is not subject to decomposition from the perspective of a specific application

Data exchange: the storing, accessing, transferring and archiving of data

Data: a representation of information in a formal manner suitable for communication, interpretation, or processing by human beings or computers.

Directed acyclic graph (DAG): a collection of nodes and directed links such that no node is an ancestor (or descendant) of itself.

Information model: a formal model of a bounded set of facts, concepts or instructions to meet a specified requirement.

Mechanical Part: a physical object that can be formed from material into a static shape.

Presentation: the act of presenting information. The concepts necessary to create a presentation of information (often product information) through some form of sensory method. The sensory methods would include visual, tactile, auditory, and olfactory.

Process: an activity that adds value to it's *input* and creates an *output*.

Product: a thing or substance produced by a natural or artificial process.

Product Data: a representation of information about a product in a formal manner suitable for communication, interpretation or processing by human beings or by computers.

Product Definition (IPLC): Within the Idealised Product Life-Cycle defined within this report Product Definition is the information created by the Design Process which is necessary to fully define a Product and allow the manufacture, operation, support and disposal of the Product.

Property: the quality, attribute or distinctive features of a thing. Properties of a product are the concepts that characterise the product. E.g. Shape, structure, thermal behaviour, material type.

Representation: the act or instance of one thing standing as an equivalent of another thing.

Supply Chain: A term for the layers of processes involved in the design or manufacture of a product. These processes may be carried out within a single company or may be carried out by different companies. A company designing (or making) an area of a product may subcontract parts of the design (or manufacture) to companies within the supply chain.

Appendix C - Definition of Information Flows in the IPLC

Actual Product - The Make process creates the actual physical products. In addition to this information about the actual product will be required. For instance the serial number of the product and the parts used in its construction may be recorded. This information flow is the equivalent of the Factory Capability and hence must support the concepts described in Capability below.

Business Management - This information flow controls and constrains the product life cycle processes.

Examples

- The plan or time scales in which the process should be carried out.
- The laws or regulations that constrain how the work should be performed or how the product should be defined.
- The business approval to move from one stage to another.

Capability is the definition of what each factory is able to achieve:

- **Make Factory**
- **Support Factory**
- **Operator**
- **Disposal Factory**

For instance during the design process the size of the machine tools in the Make Factory may be relevant if the product being designed is larger than previous ones.

If a new Make Factory is being created to support a new product then the information flow into the design process will contain the definition of the factory at its design stage rather than the actual capability that exists.

This information flow is equivalent to either Product Definition or Actual Product described above.

Concept - A definition of the product that defines its key attributes. The key attributes or properties may well vary depending on the type of product. They would normally include aspects of

- the functional design
- the physical design
- information about the likely manufacture, operation and support of the product.

The information content is similar to the Product Definition but the level of detail and degree of confidence in the data is less than when a full design has been performed. This would often be used to sell a concept to a customer who is sponsoring the design of a new product. It would also be used in obtaining the funding to fully design and detail the product.

Experience - When a product is manufactured, operated, supported or disposed of then experience of those processes and information about the product is often generated.

Examples:

- Information about how easy the product is to manufacture and how it could be changed to make it cheaper to produce.

- Within the aerospace industry products such as aircraft engines often have their performance monitored. This can be used to predict maintenance issues. The actual performance of the product can be used in the design process to improve future products.
- The support process may encounter problems when maintaining or repairing the product and this information would be passed back into the design process.

Product Definition - the collection of attributes about the product that will allow it to be manufactured, operated, supported and disposed of. This information is the same as **Concept** but all of the information necessary is fully defined whereas at the Concept stage it is only defined to a level to reduce any business risk to an acceptable level. This information flow is the equivalent of the Factory Capability and hence must support the concepts described in Capability.

Recycled Material - The disposal process will recycle any material from the product that is of any use. This in its turn will be used in the production of other products.

Requirement - the statement of functionality that the product is required to achieve. This will usually consist of a combination of the various properties of the product, e.g. shape, weight, and behaviour. In addition to these requirements a customer may also specify the cost of the product and when it should be available. This information would normally be input into the Business Management processes.

Used Product - the actual product as or after it has been operated for some time.

Appendix D - Frequently Asked Questions

1. Can the shape of an actual product change or is it fixed? - The shape of all products can change. Consider a metal block, which will expand with temperature or a parachute that has a different shape depending if it is packed or in use. No product has a totally fixed shape however for many products the changes are very small and are not significant and hence are often ingored.
2. Why is Test not one of the processes in the IPLC? - Testing a product can occur within any of the IPLC life cycle processes. Typically Products are tested within Design, Make, Operate and Support.

Appendix E - IPLC - IDEF0 Process Models

This appendix contains formal Process Models in IDEF0 format to support the models in the body of the paper.

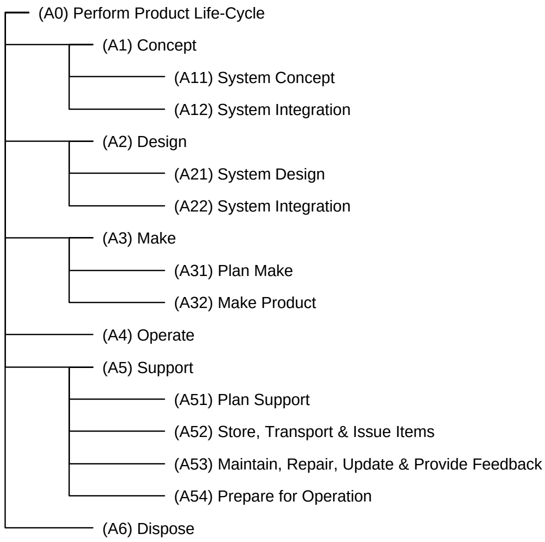
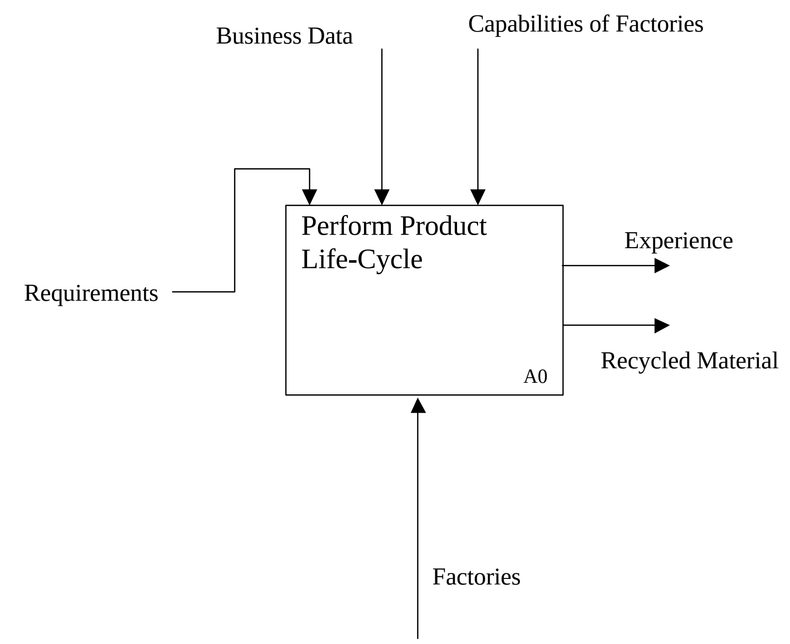


Figure 48 - IDEF0 Process Node Tree

USED AT:	AUTHOR: C E Vaughan PROJECT: Industrial Framework Model NOTES:	DATE: 14 Dec 1998 REV: 0.95		WORKING	READER	DATE	CONTEXT
			X	DRAFT			
				RECOMMENDED			Top
				PUBLICATION			



NODE: A-0	TITLE: Context	NUMBER:

Figure 49 - A-0 Context

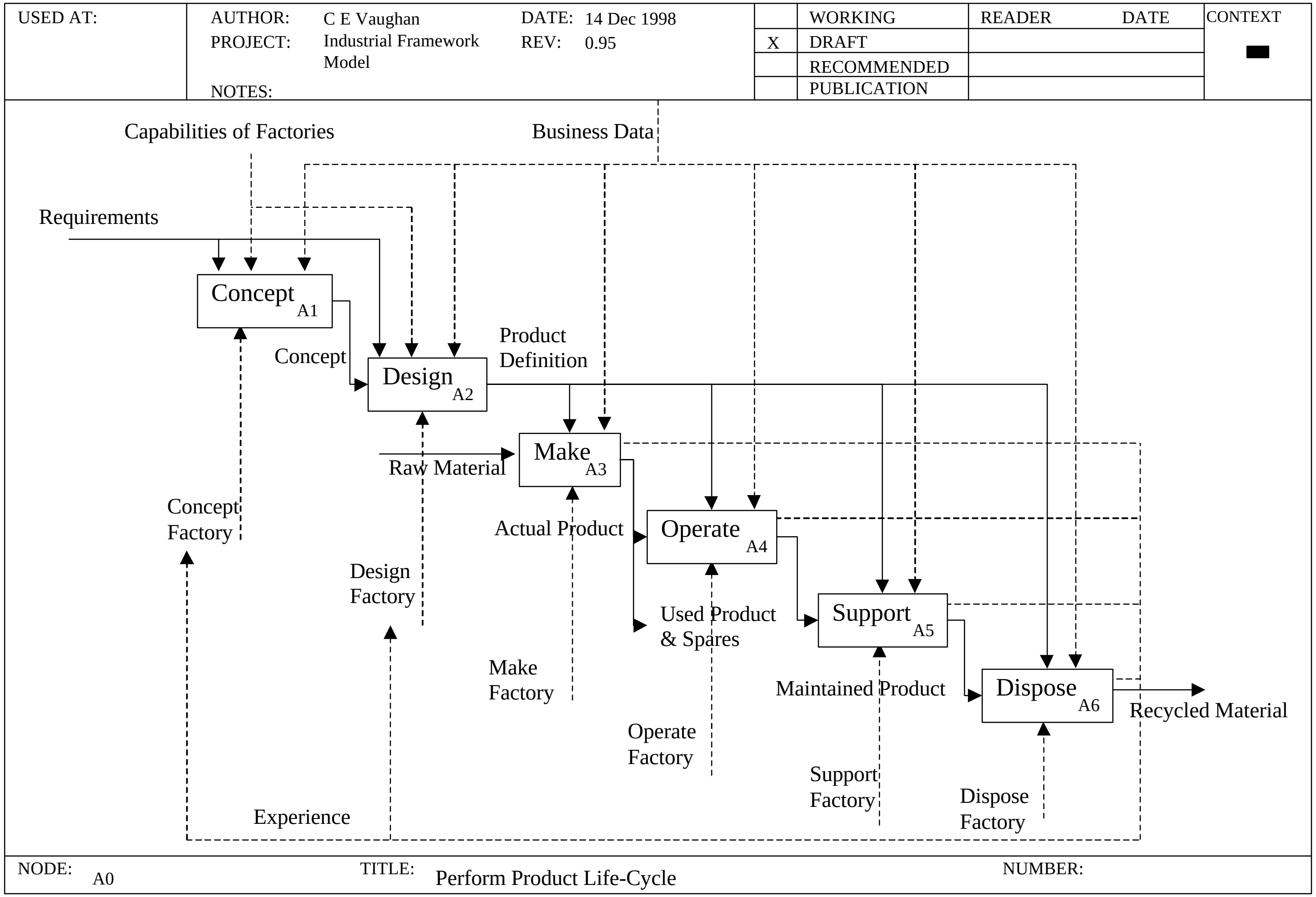


Figure 50 - A0 Perform Product Life Cycle

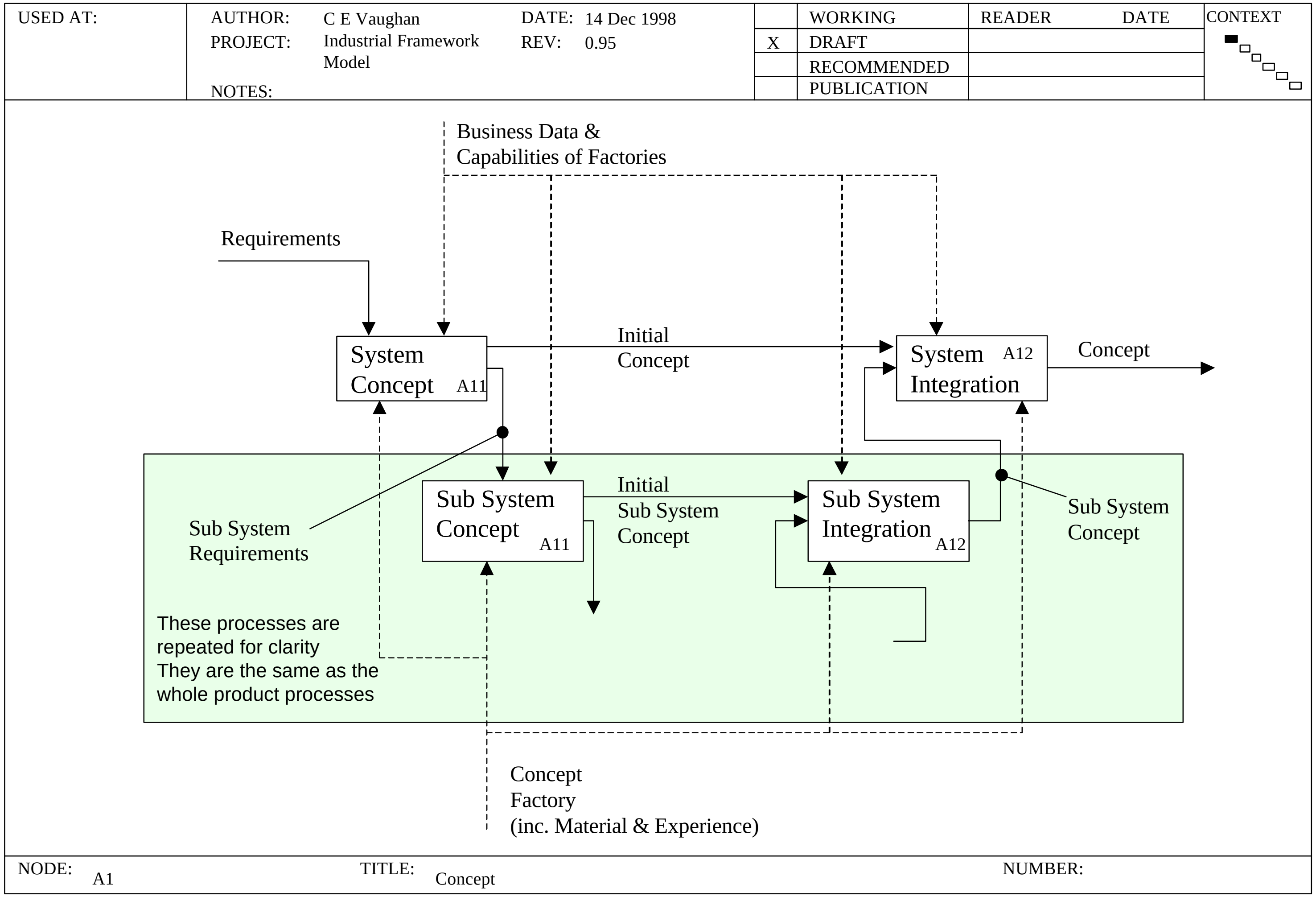


Figure 51 - A1 Concept

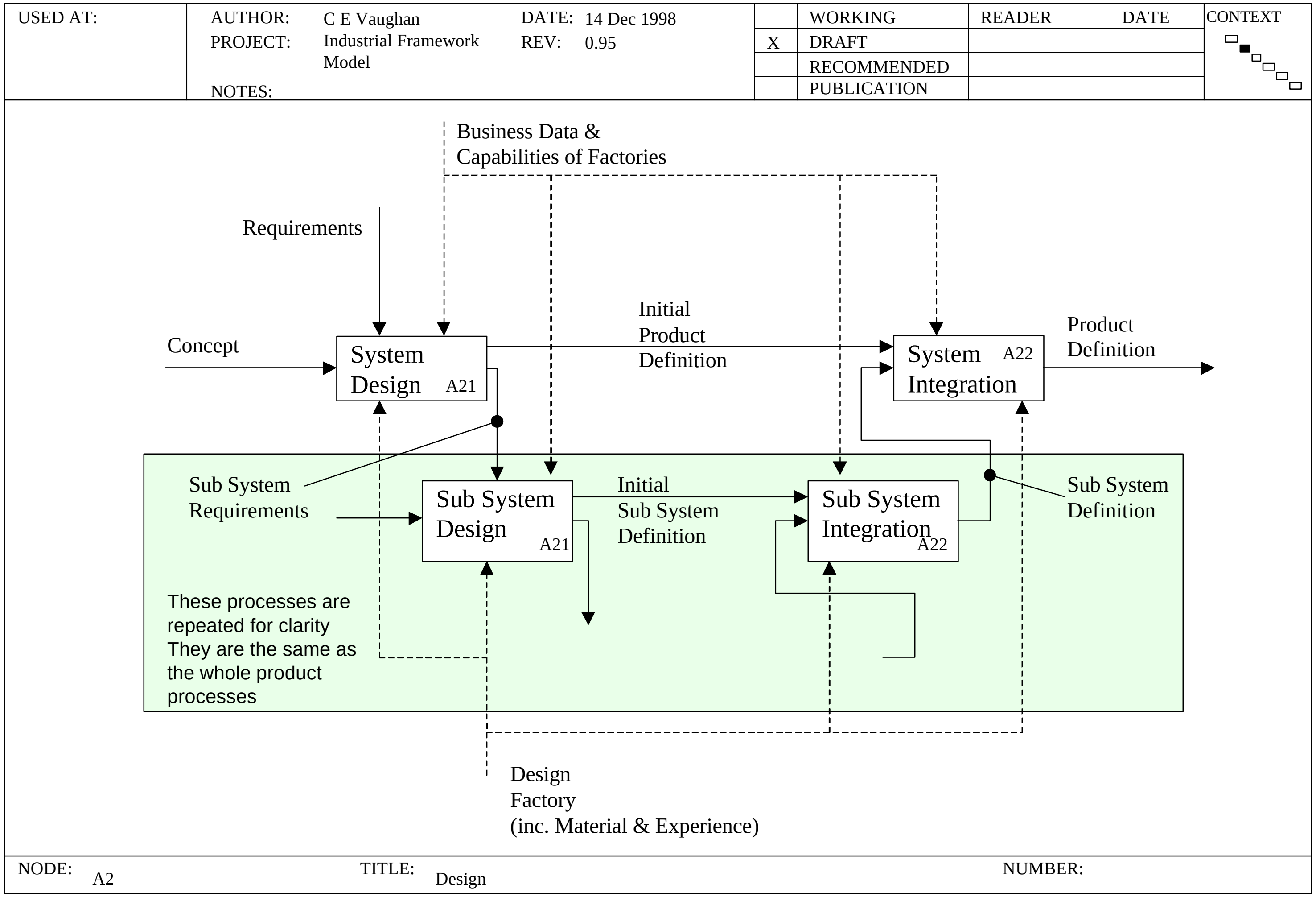


Figure 52 - A2 Design

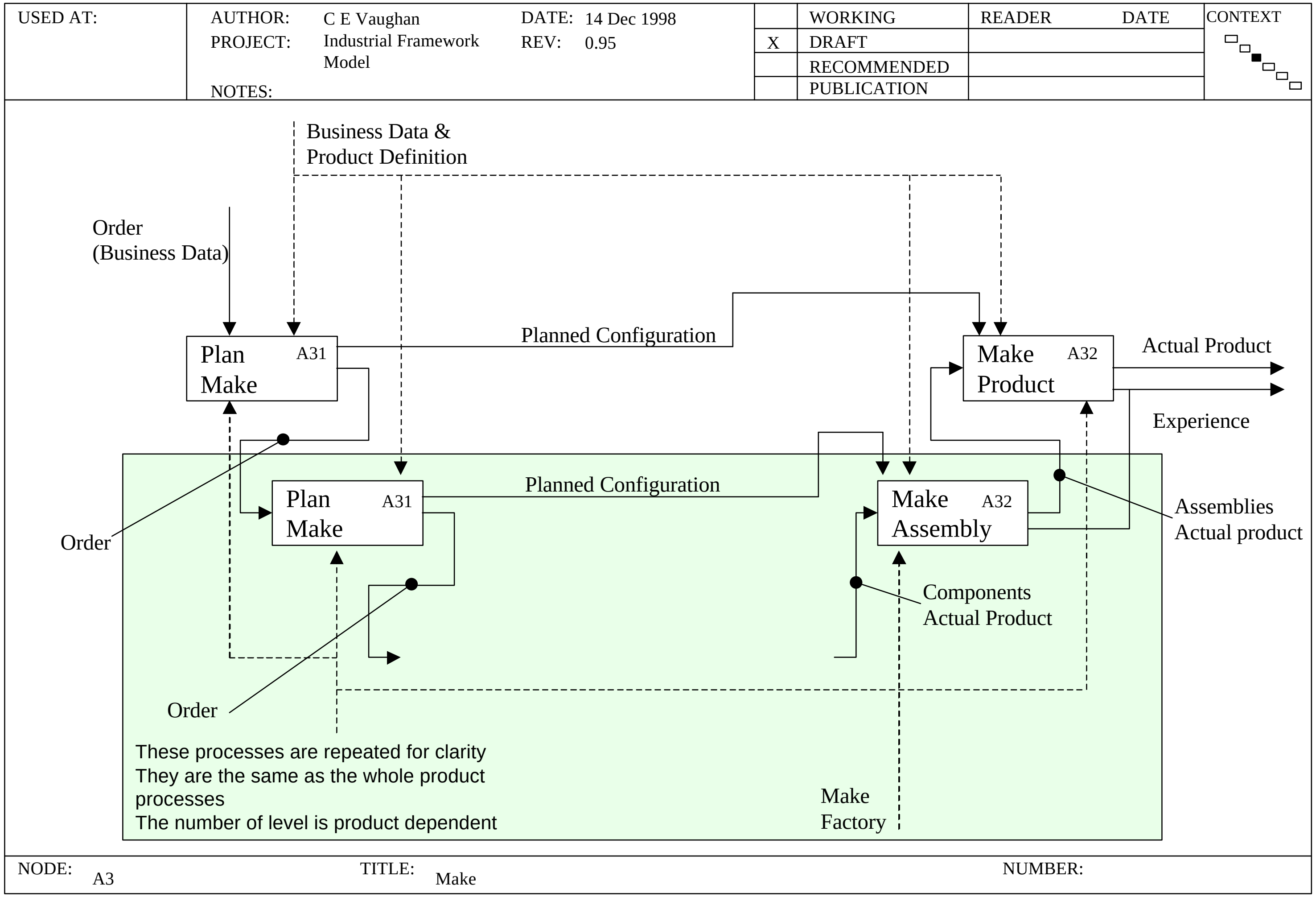


Figure 53 - A3 Make

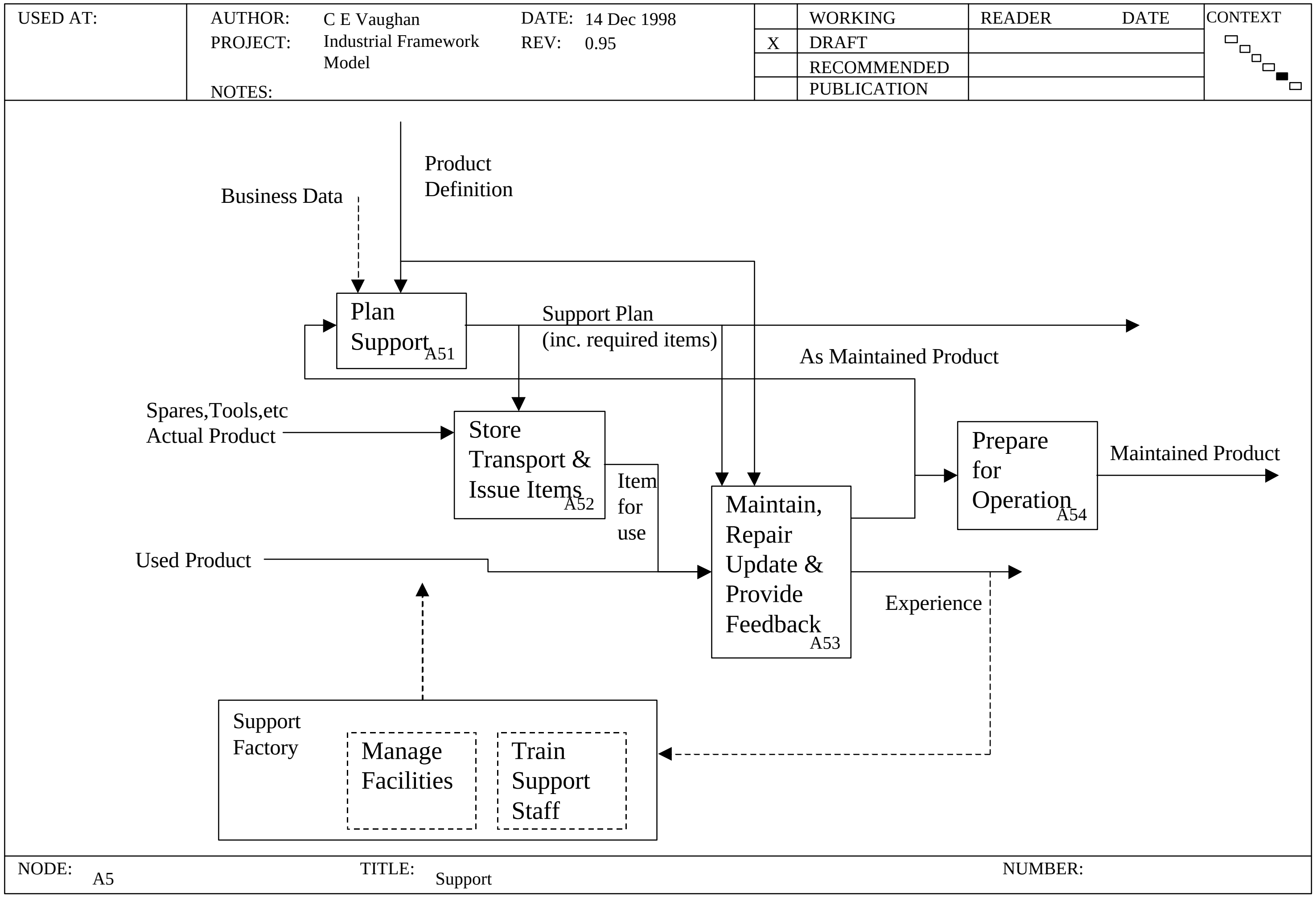


Figure 54 - A5 Support